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Image Velocity Sensor Subsystem (IVSS) Study Final Report

Volume IV: EXPERIMENT AND HUMAN FUNCTION DEFINITION

NOVEMBER 1964

Prepared for

HEADQUARTERS, SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Los Angeles, California

Contract No.: AF04(695)-656

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SSD-TR-64-237 (IV)

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Image Velocity Sensor Subsystem (IVSS) Study Final Report

Volume IV : EXPERIMENT AND HUMAN FUNCTION DEFINITION

Prepared by the

Advanced Systems Research Staff

IBM Space Guidance Center, Owego, New York

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NOVEMBER 1964

Prepared for

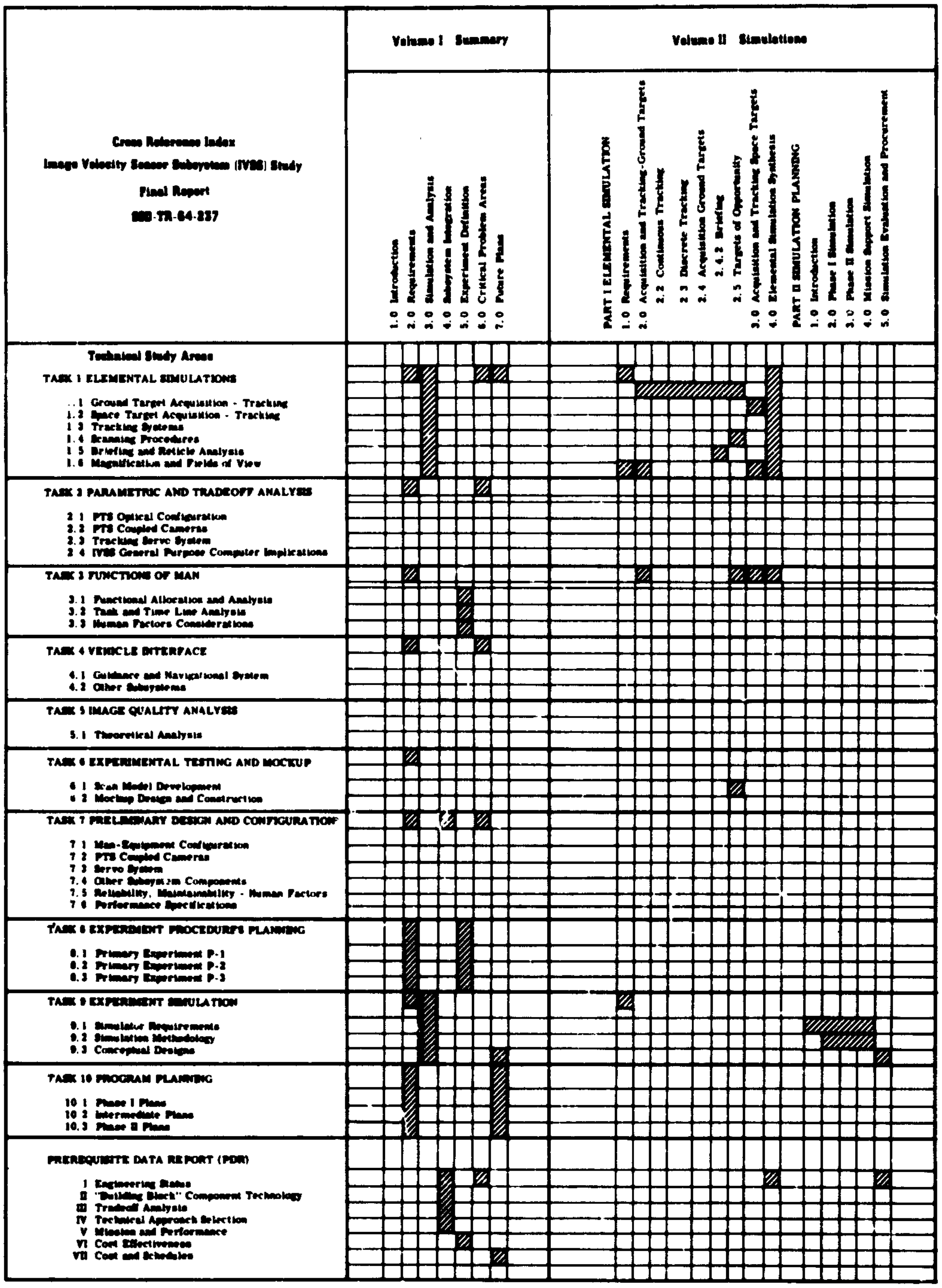
HEADQUARTERS, SPACE SYSTEMS DIVISIONS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Los Angeles, California

Abstract

The five volumes making up this Technical Documentary Report describe the results of a 3-month study of the Image Velocity Sensor Subsystem conducted for the Space Systems Division of the Air Force Systems Command under Contract AF04(695)-656. This study involved the analyses, parametric studies, simulations, preliminary design efforts, and planning necessary to develop meaningful definitions of the experiments and experimental hardware required to fulfill the objectives of the MOL program.

Volume I summarizes the entire study. Volume II presents the results of an elemental simulation program conducted to assess man's ability to perform the planned experiments. Simulation plans are also discussed in this volume. The results of trade-off and equipment design analyses are given in Volume IV, while Volume V presents detailed plans for conducting subsequent phases of the IVSS program.

In general, this study has demonstrated the basic feasibility of the proposed MOL experiments, indicated the high degree of precision that human participation can provide to the system, and developed designs and plans compatible with MOL program guidelines.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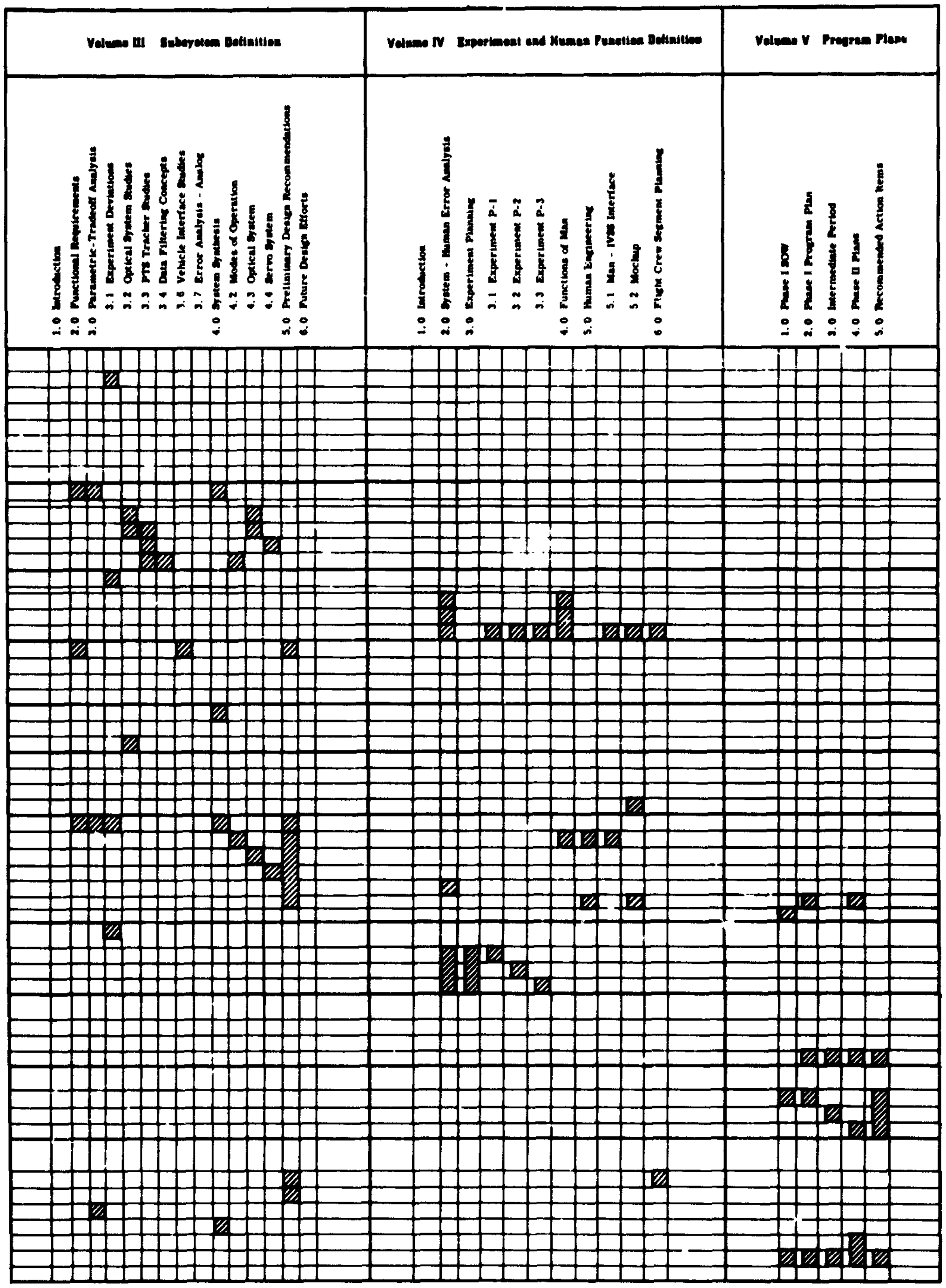
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Included in Volume IV are the results of Task 3, "Functions of Man", Task 6, "IVSS Console Mock-Up", Task 7, "Human Engineering in Subsystem Design", and Task 8, "Experiment Procedures Definition". The volume is organized about three major considerations in the incorporation of man in the Image Velocity Sensor Subsystem and the assessment of his many and varied potential areas of contribution. The organization is as follows:

- Human task and functional analyses
- The man-IVSS interface and human engineering considerations
- Definition of experimental procedures.

Analysis of human error and assignment of a system error budget and error assessment technique has received major emphasis and is reported in Section 2.0. Requirements for additional study during Phase I, in the three areas identified above, is included.

1.0 Introduction and Summary

A primary application of the IVSS will be the assessment of human contribution to the acquisition, tracking, and precise image velocity determination of terrestrial and space targets under a variety of operational and environmental constraints. Analysis of photographic data and determination of results will be accomplished on the vehicle. Also, man's capabilities and limitations as an interpreter of photographic data and experiment results will be assessed. Emphasis has been given during this study to the human element in systems design, in planning orbital experiments, in defining simulation, and in establishing training and selection requirements. This volume includes considerations of incorporating human functions and capabilities with regard to system design and assessment of human functions and capabilities by orbital experiments. Flight Crew Segment requirements are outlined, including the functions of the crew, the operator-IVSS interface, and other related functions. An approach to refinement of the man-system interface and experiments during Phase I is included.

1.1 Primary Experiments and Major Objectives

The assessment of man's contribution to acquisition and tracking of terrestrial and space targets will be by means of three primary experiments designed primarily along the continuum of target types, target dynamics, inherent target characteristics, and knowledge of target location and characteristics. The primary experiments are as follows:

- Primary Experiment P-1 - Acquisition and Tracking of Preassigned Ground Targets
- Primary Experiment P-2 - Acquisition and Tracking of Targets in Coplanar Orbits and in Fly-by-Maneuvers
- Primary Experiment P-3 - Acquisition and Tracking of Targets of Opportunity on Land and on the Oceans

The experiments will be conducted in parallel during the initial 30-day orbital deployment of the laboratory, permitting assessment of human capabilities over a period adequate to sample dynamics, environmental conditions, and effects of length of human exposure to orbital flight. Subsequent experiments will be conducted based upon the results and conclusions of the initial flight. The objectives of the primary experiments and operational constraints have necessitated division of the primary experiments into subexperiments, which are defined in Section 3.0, "Experiment Procedures Planning".

A representative orbital altitude and inclination of the laboratory has been examined with respect to the availability of targets, crew time constraints, and expected environmental conditions. The constraints imposed by these

factors were utilized in experiment planning, as well as in determining crew time and scheduling requirements. The total crew time required for these experiments over a nominal 30-day mission is 84 hours and 40 minutes, preferably divided equally between the two crew members. Of this, 40 hours and 30 minutes will be devoted to on-board measurement and analysis of photographic data (which is recommended as a method of overcoming data reduction problems), ''thru-put'' time constraints, and difficulties inherent in early return of data required for "knowledge of results" and course of action of a sequential design is used. It is felt that assessment of human contribution at this level is essential to the success of the experiments. Crew time requirements are summarized in Table 3-1.

1.2 Human Functions and Contributions

The primary experiments are designed to assess human reliability and contribution to acquisition and tracking of targets, with the IVSS serving as a tool or medium for satisfying experiment objectives. Section 4.0 describes the human functions in graphic task analysis format with time line analyses included. Once the human functions and system functions were established and allocated, crew schedules for conducting the primary experiments were completed. These schedules are in Section 3.0.

1.3 Console Layout and Subsystem Interface Considerations

The Image Velocity Sensor Subsystem Interface is designed and configured to meet the requirements of assessing the boundaries of human contribution to the acquisition and tracking of terrestrial and space targets. The console layout and rationale for configuration of the interface are presented in Section 5.0. Attention was paid not only to the primary IVSS experiments, but to the probable requirements and configuration for a two-man operational console reflecting the total experimental package. The console reflects a functional approach to the man-system interface problem. During Phase I, as system design progresses, the interface will undergo significant changes in form. The mock-up, described in Section 5.4, was developed to illustrate the operator-IVSS interface in three dimensions and will provide a work station for control display layout refinement and operator procedures evaluation during Phase I.

During IVSS trade offs and system analysis, human factors considerations and requirements for assessment of human contribution were periodically reviewed by engineering management. Trade offs in system design were weighed against the objectives and the implicit subsystem requirements of Primary Experiments P-1, P-2, and P-3.

2.0 Measurement of Human Contributions and System Error

It is desirable to establish limits of human capabilities as a function of mission constraints, dynamics, environmental conditions, and the physiological and mental state of the crew member. An error budget has been established for the entire IVSS, including the crew member/experimenter. Knowledge of the error sources in the system and provision for measurement and/or calibration of these error sources will permit on-board and ground assessment of human contribution in both a test specific and in a general or predictable sense, as well as reconstruction of the test case on the ground. Care has been exercised in the approach to system design and method of measurement to insure that human capabilities measurement is not confused with or limited by some system or environment characteristic. Section 2.1 describes the approach to isolation of error sources in the IVSS, while Section 2.2 considers human contribution and establishing boundaries for prediction. The optical and photo-optical requirements have been established to meet the experimental requirements for human contribution assessment and are included in Volume III.

2.1 Error Isolation Techniques

2.1.1 Introduction

This section discusses the methods of experiment performance and evaluation and presents techniques for identifying the components contributing to the total performance error and evaluation error.

The total system capability to perform image motion compensation to a given criteria is evaluated by photographic data analysis, and vehicle and PTS parameters. Section 2.1.2 presents an estimate of errors in this evaluation technique.

In assessing the capability or limitations of a specific system it is desirable to know if and how this system may be improved. After the total errors have been determined (pointing error in the case of target acquisition, and percent error in LOS angular rate in the case of target tracking), it is significant to identify the total error in terms of the operator and system components error. This error isolation is discussed in Section 2.1.3. Two evaluation techniques have been pursued.

The first study approach for measurement or assessment of errors involved with the experiment performance has been:

- To identify from simulation studies and state-of-the-art instrumentation analyses the most meaningful error sources involved with experiment performance
- To estimate the impact of these errors on the operational system performance

- To evaluate the instrumentation or computational "expense" of evaluating these errors in space.
- To recommend, on the basis of tradeoff considerations of calibration equipment requirements vs additional system capability, whether to perform error measurement by direct attachment of accurate devices.

The alternative, for error sources, that may be bounded and well defined for the in-space operational system by ground testing, would be to assess the error source for an error budget. This error budget, applied to the total measured system error, would assess certain error sources, directly measure other error sources, and deduce the remainder (the object of the breakdown).

The second approach has been a preliminary investigation for error reduction by employing an IMC filter (Kalman) for sensitive state vectors of the vehicle and PTS. This technique is discussed in Volume III, Section 3.4.

2.1.2 <u>Errors in the Experiment Evaluation Technique</u>

This section discusses the procedure and errors in evaluating the total system capability to perform image motion compensation (IMC) and the accuracy of target fix taking.

2.1.2.1 IMC Evaluation Error

The criteria of the percent IMC is specified as:

$$\text{percent IMC} = \frac{\text{Error in LOS Angular Rate}}{\text{LOS Angular Rate}} \quad . \qquad (2\text{-}1)$$

The total system capability to perform image motion compensation to a given criteria is evaluated by photographic data analysis.

The error in LOS angular rate ($\Delta\dot{\theta}_{LOS}$) will be determined from pairs of photographs by measuring the change of LOS angle ($\Delta\theta_{LOS}$) to target from photo to photo, such that:

$$\Delta\dot{\theta}_{LOS} = \frac{\Delta\theta_{LOS}}{\Delta T} \quad . \qquad (2\text{-}2)$$

The experiment evaluation error in determining the error in the LOS angular rate are those involved with the photo-interpretation of the hardcopy photographs. Image motion as a function of time will be measured as the difference in recording camera crosshairs and target separation from photograph to photograph by use of a film comparator.

2.1.2.1.1 Photo-Interpretative Error Sources - The evaluation errors identified with the comparison measurement are:

- Positioning resolution of operator, i.e., the accuracy to which he can lay comparator crosshairs on film
- Film comparator readout error
- Uncertainty of target center due to image resolution.

The positioning resolution of the operator is more precisely a visual limitation. Assuming a well defined, high-contrast target on the photograph, then the operator can place the film comparator crosshair on this target only to within the resolving limit of the eye. Therefore, the first item may be assessed in terms of the eyepiece magnification of the film comparator.

2.1.2.1.1.1 Resolving Limit of Eye vs Eyepiece Magnification - Assuming a minimum resolution of the eye as 1.0 $\widehat{\text{minute}}$ at the nearest point of the eye (assumed 250 cm, or approximately 10 inches); then, the resolving limit with a comparator eyepiece of magnification, M, is:

$$\frac{1\ \widehat{\text{minute}}}{M} \quad . \tag{2-3}$$

Table 2-1 gives the equivalent resolution on the film for several eyepiece magnifications and several eye relief factors. It is recommended that an eye relief factor of 3 to 5 be used in order to avoid eye fatigue. The uncertainty on the film is:

$$d_{film} = r\theta = (10 \text{ in.})\left(\frac{60\ \widehat{\text{sec.}}}{M}\right)(4.84 \times 10^{-6} \text{ rad/sec.})(25.4 \text{ mm/in.}) \tag{2-4}$$

Table 2-1
EQUIVALENT FILM RESOLUTION

Comparator Eyepiece Magnification	Minimum Resolving Limit: Equivalent Resolution On Film, Inches	Minimum Resolving Limit: Equivalent Resolution On Film, Microns	Eye Relief Factor = 3.: Equivalent Resolution On Film, Inches	Eye Relief Factor = 3.: Equivalent Resolution On Film, Microns	Eye Relief Factor = 5.: Equivalent Resolution On Film, Inches	Eye Relief Factor = 5.: Equivalent Resolution On Film, Microns
25x	1.16×10^{-4}	2.950	3.48×10^{-4}	8.850	5.8×10^{-4}	14.750
50x	5.30×10^{-5}	1.475	1.74×10^{-4}	4.425	2.9×10^{-4}	7.375
100x	2.90×10^{-5}	0.737	8.7×10^{-5}	2.210	1.45×10^{-4}	3.680
150x	1.93×10^{-5}	0.491	5.8×10^{-5}	1.470	9.65×10^{-5}	2.450
250x	1.16×10^{-5}	0.295	3.48×10^{-4}	0.850	5.8×10^{-5}	1.470

A recommendation for eyepiece magnification will be made after the magnitude of the other error sources are examined, so that this error source can be made small with respect to the others.

2.1.2.1.1.2 Photo Comparator Readout Error - The Mann Film Comparator, Model 829C, is recommended for the photo-interpretation task. The over-all accuracy of the instrument exclusive of the human error or image error is a position error of not more than 0.001 mm or 0.001 percent of the stage travel, whichever is greater. For the 70-mm film, the accuracy would be the 0.001-mm figure.

2.1.2.1.1.3 Uncertainty of Image Resolution - This last error source is assessed as being limited by the photographic resolution. The rationale for this assessment is that the accuracy of measurements between photographs approaches the repeatibility of measurements of of a single photograph within the limitations of the film graininess. This logic is valid if the photo pair is separated by a sufficiently small time interval so that the optical errors are repeatible due to nearly identical optical conditions, viewing aspect, contrast ratio, etc. The logic is substantiated by examining the total error contributors of the measurement of the LOS rate ($\epsilon_{\Delta \dot{\theta}}$) and demonstrating that these measurement errors are tolerable for a small time interval between photographs. The error has been previously related to the error in crosshair and target separation, $\epsilon_{\Delta \theta}$, so that in terms of the enumerated error sources

$$\epsilon_{\Delta \dot{\theta}} = \frac{\epsilon_{\Delta \theta}}{\Delta T} = \frac{\sqrt{\epsilon^2_{\text{Comparator}} + \epsilon^2_{\text{Visual}} + \epsilon^2_{\text{Film}}}}{f \Delta T} \tag{2-5}$$

where the error contributors are equivalent distances on the film and f is the focal length of the optical system.

2.1.2.1.1.4 Required Photo Measurements for Small Time Interval Between Photographs - To determine the time between photo pairs (ΔT) it is necessary to establish the nagnitude to which $\Delta \dot{\theta}_{LOS}$ must be determined and the magnitude to which $\Delta \dot{\theta}_{LOS}$ can be measured.

Table 2-2 gives the error in LOS rate as a function of percent IMC based on the LOS rate at an altitude of 160 n mi, and an orbital velocity of 25,000 ft/sec. That is, from percent

$$\text{IMC} = \frac{\text{Error in LOS Angular Rate}}{\text{LOS Angular Rate}}$$

where the LOS angular rate $\dot{\theta}$ at nadir is

$$\dot{\theta}_N = \frac{V}{H} = \frac{25{,}000 \text{ ft./sec.}}{160 \text{ mi.} \times 6000 \text{ ft./min.}} = 0.026 \text{ rad./sec.},$$

$$\dot{\theta}_N = 5400 \ \widehat{\text{sec}}/\text{sec.}$$

The angular rate at nadir does not represent the worst case in terms of smallest $\Delta\theta$ to be measured (this would occur at the large slant viewing angles); however, it is more representative of when the photo-interpretative measurements would be made, so that

$$\Delta\dot{\theta}_{LOS} \text{ (required)} = \text{percent IMC} \times \dot{\theta}_N .$$

Table 2-2
ALLOWABLE ERROR IN LOS RATE AT NADIR

Percent IMC	$\Delta\dot{\theta}$ ($\widehat{\text{sec.}}$/sec.)
0.20	10.80
0.10	5.40
0.05	2.70
0.02	1.08

The required time between photographs may be computed by invoking the constraint that the measurement error, $\epsilon_{\Delta\theta}$, be some fractional part, κ, of the error in the LOS angle $\Delta\theta$, so that:

$$\Delta T \geq \frac{\text{achievable measurement accuracy}}{\text{required rate limit for percent IMC}}$$

or

$$\Delta T \geq \frac{1/\kappa\sqrt{\epsilon^2_{\text{Comparator}} + \epsilon^2_{\text{Visual}} + \epsilon^2_{\text{film}}}}{\text{required rate limit for percent IMC}} \qquad (2\text{-}6)$$

It must be remembered that to vindicate the premise that image uncertainty will be limited by film graininess, the computed ΔT should satisfy the conditions for nearly identical viewing conditions between photographs.

2.1.2.1.1.5 Film Graininess Limitation - The error contributed by the graininess of the photographs is the rms value of the distance between the actual center and the measured center of a circular target and is given by

$$\frac{24g}{C'}$$

where g is the rms granularity as published by Eastman Kodak for their films, and C' is related to the target contrast.

C' is related to the target contrast C at the periscope objective by

$$C' \approx C/\left[1 + \left(\frac{2\theta_{RF}}{\theta t}\right)^2\right] \qquad (2\text{-}7)$$

where θ_{RF} is the angular resultion of the photo-optical system and is the angular subtension of the target. Table 2-3 gives the film

resolution error as a function of θ_{RF}/θ_t for Kodak films S0-243 and S0-226. The target contrast is taken as 0.6 and Kodak gives g = 0.016 for S0-243 and g = 0.031 for S0-226.

Table 2-3
FILM RESOLUTION ERROR

θ_{RF}/θ_t	0.25	0.50	1.00
S0-243	5.4	6.9	14.2
S0-226	7.8	11.4	26.6

Assuming θ_{RF}/θ_t not to exceed 0.5, it follows from the table that the film graininess error will not exceed 6.9 microns for the slower S0-243 film. Therefore, the total measurement error of each photograph point from Equation (2-6) is assessed as

$$\epsilon_{(X,Y)} = \sqrt{\epsilon^2_{Comp} + \epsilon^2_{Visual} + \epsilon^2_{film}}$$

$$\epsilon_{(X,Y)} = \sqrt{1.0^2 + 0 + 6.9^2} \simeq 7.0 \text{ microns} \qquad (2\text{-}8)$$

where the visual error due to limitations of comparator eyepiece is considered ignorable by merit of selection of an eyepiece where

$$\epsilon_{Visual} \leq 1.0 \text{ microns.}$$

2.1.2.1.2 Photo-Comparison Technique Errors - The previous error assessment is for the measurement of the X and Y coordinates of cross-hairs and targets respectively. The value for $\Delta\theta$ is computed from these readings. It would be desirable to overlay the photographic negatives to measure the change; however, the problem of photograph alignment and viewing through two films appear less accurate than the direct measurements on each photograph. The following derivation gives the distance computation, Δ d, in terms of the measurements from the photographs.

Consider that the measurements are made from the photos in Figure 2-1. The photos, if superimposed would appear as in Figure 2-2. If the cross-hairs and targets were aligned, they would appear as in Figure 2-3.

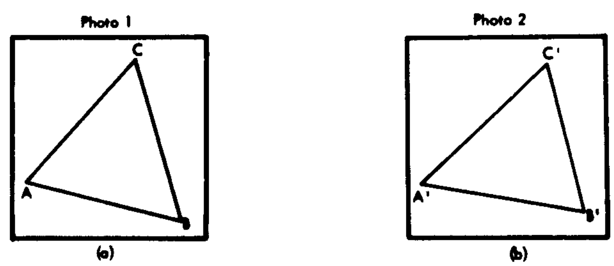

Figure 2-1. Photo-Comparison Technique

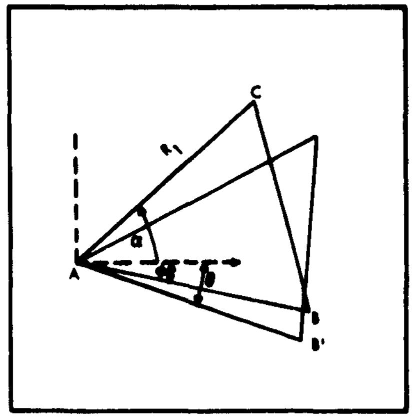

Figure 2-2. Superimposed Photographs

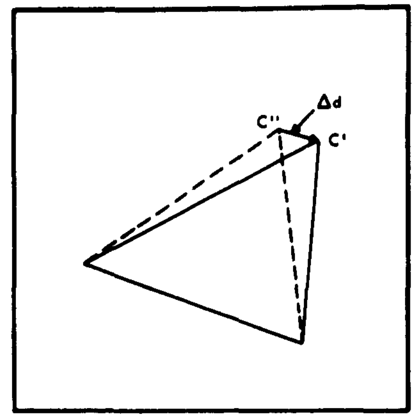

Figure 2-3. Crosshairs and Targets Aligned

Assuming superposition and prominent landmarks A and B to be identical to A' and B' (which can be verified by a validity check):

$$(X_A - X_B)^2 + (Y_A - Y_B)^2 = (X_{A'} - X_{B'})^2 + (Y_{A'} - Y_{B'})^2 \ .$$

From the measurements

$$X_A;\ Y_A;\ X_B;\ Y_B;\ X_C;\ Y_C;\ X_{A'};\ Y_{A'};\ X_{B'};\ Y_{B'};\ X_{C'};\ Y_{C'}$$

$$\phi = \tan^{-1}\left(\frac{Y_B - Y_A}{X_B - X_A}\right); \quad \theta = \tan^{-1}\left(\frac{Y_{B'} - Y_{A'}}{X_{B'} - X_{A'}}\right)$$

Rotating B to B' and C to C'' via the angle $(\theta - \phi)$.

$$\alpha = \tan^{-1} \frac{Y_C - Y_A}{X_C - X_A}$$

so that $= \alpha' = (\theta - \phi)$

and $X_{C''} = R_1 \cos \alpha'$ and $Y_{C''} = R_1 \sin \alpha'$

where $R_1 = \left[(X_C - X_A)^2 + (Y_C - Y_A)^2\right]^{1/2}$

The desired $\Delta d = \left[\left(X_{C'} - X_{C''}\right)^2 + \left(Y_{C'} - Y_{C''}\right)^2\right]^{1/2}$,

$$\Delta d = \left[\left(X_{C'} - \left[R_1 \cos \alpha'\right]\right)^2 + \left(Y_{C'} - \left[R_1 \sin \alpha'\right]\right)^2\right]^{1/2} ,$$

which in terms of the measured parameters is:

$$\Delta d = \Bigg[\Bigg\{X_{C'} - \left[(X_C - X_A)^2 + (Y_C - Y_A)^2\right]^{1/2} \cdot \cos\left\{\tan^{-1}\left(\frac{Y_C - Y_A}{X_C - X_A}\right) - \tan^{-1}\left(\frac{Y_{B'} - Y_{A'}}{X_{B'} - X_{A'}}\right) + \tan^{-1}\left(\frac{Y_B - Y_A}{X_B - X_A}\right)\right\}\Bigg\}^2 + \Bigg\{Y_{C'} - \left[(X_C - X_A)^2 + (Y_C - Y_A)^2\right]^{1/2} \cdot \sin\left\{\tan^{-1}\left(\frac{Y_C - Y_A}{X_C - X_A}\right) - \tan^{-1}\left(\frac{Y_{B'} - Y_{A'}}{X_{B'} - X_{A'}}\right) + \tan^{-1}\left(\frac{Y_B - Y_A}{X_B - X_A}\right)\right\}\Bigg\}\Bigg]^{1/2}$$

Now for $u = f(X_1, X_2, \ldots X_n)$,

$$du = \frac{\partial f}{\partial X_1} dX_1 + \frac{\partial f}{\partial X_2} dX_2 + \ldots + \frac{\partial f}{\partial X_n} dX_n \quad . \qquad (2\text{-}9)$$

For this case, considering $dX \sim \Delta X_n = \Delta X_{n-1} = \Delta Y_n = \Delta Y_{n-1}$

$$\epsilon_{\Delta d} = \Delta X \left\{ \frac{\partial \Delta d}{\partial X_A} + \frac{\partial \Delta d}{\partial Y_A} + \frac{\partial \Delta d}{\partial X_B} + \frac{\partial \Delta d}{\partial Y_B} + \frac{\partial \Delta d}{\partial X_C} + \frac{\partial \Delta d}{\partial Y_C} + \frac{\partial \Delta d}{\partial X_{A'}} + \frac{\partial \Delta d}{\partial Y_{A'}} + \frac{\partial \Delta d}{\partial X_{B'}} + \frac{\partial \Delta d}{\partial Y_{B'}} + \frac{\partial \Delta d}{\partial X_{C'}} + \frac{\partial \Delta d}{\partial Y_{C'}} \right\}$$

It becomes apparent that the partial derivatives become tremendously unwieldy for this evaluation, so to gain insight into how these measurement errors accrue, consider the geometry of Figure 2-4. One of the salient ground features will be the tracked target (say pt A), so that if the points C and C' represent the crosshairs, these points would be close together on the 70-mm film. It is assumed that there is translation but no rotation of the crosshair with respect to the ground so that the following geometry may be applied:

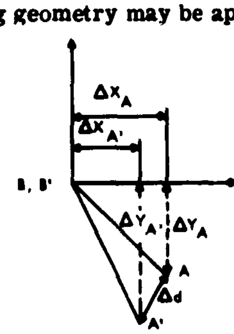

Figure 2-4
Geometry of Error

$$\Delta d \quad \sqrt{(\Delta X_A - \Delta X_{A'})^2 + (\Delta Y_A - \Delta Y_{A'})^2} ,$$

where:

$$\Delta X_A = X_A - X_B$$
$$\Delta X_{A'} = X_{A'} - X_{B'}$$
$$\Delta Y_A = Y_A - Y_B$$
$$\Delta Y_{A'} = Y_{A'} - Y_{B'}$$

$$\Delta d = \left[(X_A - X_B - X_{A'} + X_{B'})^2 + (Y_A - Y_B - Y_{A'} + Y_{B'})^2 \right]^{1/2} \quad (2\text{-}10)$$

Assuming independent errors in the measured parameters the standard deviation of $\Delta d = 2\,\sigma_{X,Y}$ so that $\epsilon_{\Delta\theta}$ = 14 microns.

2.1.2.1.3 <u>Time Between Photographs vs IMC Requirements</u> - The preceding development of measurement accuracy requirements leads to the following relationship:

$$\frac{\epsilon \text{ (measurement accuracy in microns)}}{f \Delta T\ (254)} = K\ \%\ \text{IMC}\ \left(\frac{V}{H} \cos^2\theta \right),$$

where f is focal length in inches

ΔT is the interval between photos is in seconds

K is the fractional part of the LOS rate allotted to the evaluation error procedure.

The above equation has been evaluated (for varying IMC criteria) for K = 1/5 and ϵ_d = 14 microns at nadir (as previously rationalized) to determine $f\,\Delta T$ and ΔT for the 36-inch optical system. The results are shown in Table 2-4.

Table 2-4
TIME BETWEEN PHOTO PAIRS AS CONSTRAINED BY PHOTO-INTERPRETATIVE EVALUATION ERRORS

Percent IMC	fx T (sec.) OR f T (in. sec.)	ΔT for f = 36"
0.20	53	1.4 sec.
0.10	106	2.9 sec.
0.05	212	5.9 sec.
0.02	530	14.0 sec.

These preliminary results appear to vindicate the assumptions of the analysis.

Variation must be considered in target size, requirements of the "k" factor, film selected, etc., which affect the $f\Delta T$ requirements; however, the premise of nearly identical viewing conditions appears justified. This area of analysis is recommended for more detailed considerations.

2.1.2.2 Accuracy of Target Acquisition - Evaluation

The evaluation of target acquisition parallels the evaluation of IMC with the exception of the uncertainty of the target center due to image resolution. For IMC evaluation, the measurement between photographs is a

relative measurement. The resolution is film limited. Motion of the crosshair with respect to the target can be measured even if this reference target has poor image quality as long as there is consistent image quality from photograph to photograph. However, the accuracy of target acquisition is an absolute measurement and a significant criteria of evaluation is the angular separation or equivalent ground distance of crosshair and target. This absolute definition obtained in the negative is limited by the resolving power of the lens or by that of the film emulsion used, whichever is lower.

For evaluation of the target acquisition the error in the X or Y coordinates of crosshairs and target is assessed as follows:

$$E_{(X,Y)} = \sqrt{(E_{P/O})^2 + E^2_{\text{visual}} + E^2_{\text{comp}}}\ .$$

The term $E_{P/O}$ represents a slightly different measurement hypothesis than for the case of IMC determination. The objective is the determination of a target position on a single photograph so that repeatability of the image from photo to photo is not the limiting constraint. In this case the limitation is the ability to measure the target center of an irregular shape which may be performed to within some fractional part, N. of a photo-optical resolution element. It is difficult to corroborate the estimates for this capability since most photo-interpretative measurements are limited by measurement instrumentation errors. The vindication of this assumption is made essentially on human factors studies on the capability to define the center of an irregular shape which is representative of the target image degraded by the photo-optical limitations. This capability has been estimated as one-half the photo-optical resolution. R_{FO}.

The parametric analysis of the visual-optical system made in Volume III, Section 3 sites the target acquisition capability of the operator to be within 6 to 12 seconds of arc. Anticipating the same operational system performance levels, and invoking a previous constraint than evaluation measurement errors be some fraction, K. of the performance error. the range of measurement requirements become 1.2 to 2.4 seconds of arc for K = 1/5.

With these assumptions the measurement errors may be related to the performance errors by:

$$E_{\Delta\theta} = K\Delta\theta = \frac{E\Delta d}{f} = \frac{\sqrt{\left(\frac{R_{FO}}{N}\right)^2 + E^2\ \text{visual} + E^2\ \text{comparator}}}{f} \qquad (2\text{-}11)$$

It is further assumed that:

$$E^2_{visual} + E^2_{comparator} < \left(\frac{R_{FO}}{N}\right)^2$$

which can in part be effected by the selection of the proper comparator eyepiece so that $\frac{R_{FO}}{N} > E_{visual}$ and in part vindicated by the requirements on the photo-optical resolution, R_{FO}, indicated in Table 2.5. That is, by this assumption

$$K\Delta\theta \quad (4.8 \times 10^{-6} \ \frac{rad}{sec} = \frac{R_{FO}}{25,400 \ Nf} \ ,$$

where: R_{FO} is in microns

f is in inches

$K\Delta\theta$ is in seconds of arc .

For the tabulation $1.2 \ \widehat{sec} < K\Delta\theta < 2.4 \ \widehat{sec}$ and N = 1/2 as previously described, so that:

$$R_{FO} = 0.12 \ N \ f \ (K \Delta\theta) .$$

Table 2-5

PHOTO-OPTICAL RESOLUTION REQUIRED TO EVALUATE TARGET FIX ACCURACY TO WITHIN 20 PERCENT OF EXPECTED OPERATOR PERFORMANCE

$K\Delta\theta$	f = 30		f = 36		f = 40	
	R_{FO} (Microns)	Res. In Lines/mm	R_{FO} (Microns)	Res. In Lines/mm	R_{FO} (Microns)	Res. In Lines/mm
1.2 sec.	2.1	475	2.6	385	2.8	350
2.4 sec.	4.3	232	5.2	193	5.7	175

2.1.2.3 Conclusions on Accuracy

For target acquisition determination,this exercise demonstrates that the experiment performance can be evaluated for the candidate system wherein the evaluation errors can be constrained to fractional parts of expected performance errors. The results in Table 2-5 indicate marginal design requirements, i. e., high photo-optical resolution, however, the parametric variation of K and N are significant. Normally target resolution is assessed as limited to the photo-resolution element, i. e., N = 1. Also for the confidence level of the measurement errors with respect to performance errors should be traded-off as the performance level increases. For example, for f = 36 in., N = 1, K = 50 percent for $\Delta\theta$ = 12 seconds of arc the photo-optical resolution requirements which support the evaluation technique are approximately 40 lines/mm which is well with design potential. These considerations demonstrate the considerable latitude of the design requirements as functions of the assumptions

necessary for the evaluation. This area requires additional study, especially in the photo interpretative capability when target definition accuracy approaches the resolution accuracy, however, these preliminary conclusions do support the evaluation approach.

2.1.3 Determination and Isolation of System Error Components

The photographic data analysis enables computation of the total system performance for IMC and target acquisition or fix taking for Experiment P-1.

The purpose of this analysis is to demonstrate that the system design requirements and the expected error budget for the system instrumentation are compatible with constraints for IMC performance. A second objective is that of identifying the component errors which limit the system capability. In evaluating the impact and potential for system improvement it is desirable to provide the following information: (1) an enumeration of significant errors of the IVSS system; (2) the "expense" of evaluating, measuring, or reducing the error in space, that is, estimates of either the operator line time or additional equipment which will be necessary to make these evaluations; (3) where possible, suggested techniques for evaluating these errors in space; (4) estimated error sources which can be evaluated on the basis of ground tests and be correlated to the space environment.

2.1.3.1 Reference to Error Budgets

Error budgets for the various modes of operation are summarized in Table 5-1 of Section 5.2 and are reproduced in Table 2-6 for purposes of determining impact on IMC performance capability.

2.1.3.2 Effect of Instrumentation Errors on IMC Evaluation

The estimated pointing precision and rate precision budgets must be considered because they affect the IMC performance evaluation and fix taking accuracy respectively. The IMC performance evaluation is made by relative comparison of crosshair and target displacement from photograph to photograph. Consequently, systematic errors which appear constant from photograph to photograph, i.e., that are repeatible, are bias errors in the photographs. Only those error sources which are completely random from photograph to photograph affect the IMC evaluation.

In determining the fix taking accuracy or the target acquisition accuracy, which is an absolute measurement made from a single photograph, bias errors will affect the evaluation procedure in a different manner (to be described). Further, any experiments in which pointing commands of

Table 2-6
"IVSS ESTIMATED MAXIMUM POINTING PRECISION" (In Seconds)

Error Sources	Initial Pointing	Absolute Static Pointing		Relative Pointing Modes 2 & 3		Absolute Dynamic Pointing Mode 4		Remarks
		Std.	Limit	Std.	Limit	Std.	Limit	
Man	Not	±25	±25	±25	±25	±25	±25	E.S.S. Data
Servo Static		±2.5	±2.5			—	—	See Servo Section
Servo Dynamic	Critical	—	—	± 15	±15	±15	±15	
Optical Axis Missalign		±3.0	±2.0			±3.0	±2.0	Estimated (.0005" disp)
Reticle-to-Optical Axis	Degrees	±4.0	±2.0			±4.0	±2.0	Estimated (.0005" disp)
Mechanical Mounting		±70	±17			±70	±17	Itek Data
Pitch Mirror Align	o.k.	±37	± 9			±37	± 9	Itek Data
Mechanical Bearing						±20	± 5	Itek Data
Pitch-Roll Axes Non-Orthorganality						±14	± 4	Itek Data
Inertial Reference Align						±15	±10	From Vendor Brochure
Inertial Reference Noise						±60	±4.0	
Computer and Equation Errors						±10	± 5	In-House Data and Est.
RSS (1σ)		28	11	8.5	8.5	36	17	

additional sensors are slaved to PTS pointing angles would be subject to the absolute pointing limitations.

In determining IMC performance, there is a fine line of distinction between the effect of bias errors in the angular reference which is: bias errors may effect the level of IMC performance but not the IMC evaluation. Bias error such as reticle misalignment, mechanical mountings, or mirror misalignment introduce a pointing error which will cause the target to drift because pointing commands may be resolved through this error angle. However, in the evaluation of IMC, from photograph to photograph, the bias errors do not inhibit the determination of drift of crosshair and target.

IMC determination for the prime digital mode where ephemeris updates have been made presupposes that the operator has been capable of cancelling out constant drift rates so that IMC made for post-track evaluation would be limited by the random errors when the system is operated open loop (hands-off). From the items enumerated in the error budget, it appears that the only non-predictable error from photograph to photograph is the servo resolver error which is a quantization error. Over relatively small time intervals, i.e., a few seconds, the remaining items in the budget would either be removed, repeatable, or predictable. The servo maximum dynamic error is cited as 10 seconds of arc; the 1 σ value is assumed as 3 seconds of arc. The compatibility of IMC performance and evaluation as limited by instrumentation error is demonstrated by reference to Table 2-2 of this section. Performance of IMC to 0.05 percent at the 160 n mi altitude requires that the error in LOS angular rate be less than 3 $\widehat{\text{sec}}$./sec. For a photo pair taken 10 seconds apart, the LOS angular rate error due to random instrumentation uncertainty would be 0.3 $\widehat{\text{sec}}$./sec., or 10 percent of the constrained system performance level.

2.1.3.3 Isolation of Operator Instrumentation Errors in Fix Taking Procedure

The second area of interest in the instrumentation errors and how they affect test evaluation is for the fix taking or target acquisition evaluation. The accuracy of the fix taking, that is the ability to determine when the

crosshairs and target are coincident, as limited by the operator, is recorded by the photograph taken at the time of fix. The photographic data analysis, measures the man's fix taking capability apart from the system pointing inaccuracies.

In the prime digital mode in which ephemeris updates are affected by discrete target fixes, the LOS pointing angle to the target which are read from the sensors include the pointing errors due to the instrumentation, misalignment errors and the operator error. The photo taken at the time of the fix is a method of isolating the man's performance capability. The accuracy to which the operator may be assessed is limited only by the photo-interpretative errors previously discussed.

2.1.3.4 Error Analysis for Analog Instrumentation

This section presents an analysis of errors in the design approach for the analog instrumentation for Mode 2. These comments are pertinent in the discussion of error isolation in that the capability to evaluate IMC performance in this mode is contingent upon the ability of the system to maintain IMC in open loop or hands-off operation after the operator has ceased tracking.

There are two pertinent factors pertaining to the capability of the analog systems: (1) to provide the man with sufficient computational assistance to assure that he can track to criteria, and (2) to provide a system that will run open loop in post-track operation so that the closed loop system may be evaluated.

Two analog modes have been identified, one for tracking with no system aiding, and a more sophisticated analog scheme which generates part of the required tracking function so that the system will maintain the IMC level for a sufficiently long time interval to enable evaluation of the IMC.

The evaluation procedure has been to determine the required rate generation function for a flat Earth model, to elect a candidate analog instrumentation, and to assess the drift rates which would be incurred by this system in open loop performance.

2.1.3.4.1 Derivation of Exact Tracking Function - The most general case of the required rates may be obtained from the configuration of Figure 2-5 where $\overline{R}$ and $\overline{V}$ are assumed to be misaligned by the angle β which is referenced in the roll plane to $\theta_R = 0$ by the angle α_β.

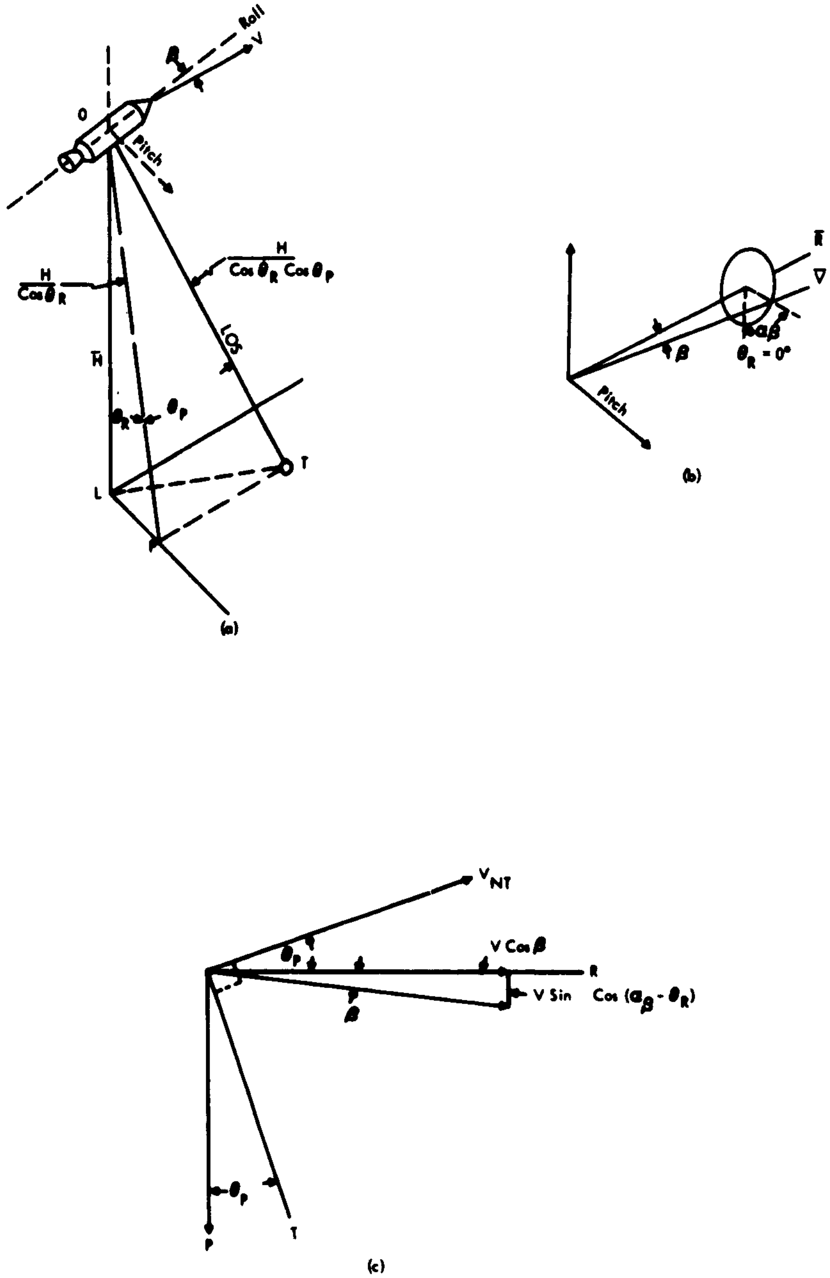

Figure 2-5. Derivation of Exact Tracking Function

The required rates as functions of V, H, θ_R, θ_P, β and α_β are developed as:

$$OT = \frac{H}{\cos\theta_R \cos\theta_P} \quad ; \quad OP = \frac{H}{\cos\theta_R}$$

$$\omega_{P_{OT}} = \frac{V_{Normal}}{OT} \text{ (in Plane OTP)}$$

In Plane OPT:

$$V_{Normal\ OT} = V \cos\beta \cos\theta_P - V \sin\theta_P \sin\beta \cos(\alpha_\beta - \theta_P)$$

$$\boxed{\omega_P = \frac{V}{H} \cos\theta_P \cos\theta_P \left[\cos\beta \cos\theta_P - \sin\theta_P \sin\beta \cos(\alpha_\beta - \theta_R)\right]} \quad (2\text{-}12)$$

Also, $$\omega_{R_{OT}} = \frac{V_{Normal\ OP}}{OP} = \frac{V \sin\beta \sin(\alpha_\beta - \theta_R)}{OP}$$

$$\boxed{\omega_{R_{OT}} = \frac{V}{H} \cos\theta_R \sin\beta \sin(\alpha_\beta - \theta_R)} \quad (2\text{-}13)$$

For the case where the misalignment between the velocity vector and the roll axis is zero or small Equation (2-12) simplifies to:

$$\omega_{P_{OT}} = \frac{V}{H} \cos^2\theta_P \cos\theta_R . \quad (2\text{-}14)$$

2.1.3.4.2 Candidate Analog Instrumentation - The candidate analog instrumentation which is recommended is one which resolves the hand control through the pitch and roll angles as in Equation (2-14) by employing the instrumentation shown later in Figure 4-3.

For the pitch rate loop, consider that the tracking ends at time t_1 and that at θ_{P1} @ t_1, the generated pitch rate is exact by assuming the astronaut's capability to effect exact tracking, then the hand control function

$\omega_{HC} = f(\theta_R, \theta_P, \beta, \alpha_\beta, \omega_{P_V})$ is resolved through θ_P and θ_R so that:

$$\omega_{HC} \cos\theta_{R1} \cos^2\theta_{P1} = \omega_{exact} = \frac{V}{H} \cos\theta_{P1} \cos\theta_{R1}$$

$$\left[\cos\beta \cos\theta_{P1} - \sin\theta_{P1} \sin\beta \cos(\alpha_{\beta 1} - \theta_{R1})\right] \quad (2\text{-}15)$$

i.e.,

$$\omega_{HC} = \frac{V}{H\cos\theta_{P1}} \left[\cos\beta \cos\theta_{P1} - \sin\theta_{P1} \sin\beta \cos(\alpha_\beta - \theta_{R1})\right] . \quad (2\text{-}16)$$

Now if the loop is allowed to run open loop for Δt, the generated $\omega_{P_{OT}}$ at θ_{P2} and θ_{R2} is the ω_{HC} signal held and resolved through the updated angles.

$$\omega_{P_{OT(2)}} = \frac{\cos\theta_{R2} \cos^2\theta_{P2} \cdot V}{H \cos\theta_{P1}} \left[\cos\beta_1 \cos\theta_{P1} \right.$$

$$\left. - \sin\theta_{P1} \sin\beta \cos(\alpha_\beta - \theta_{R1}) \right] \qquad (2\text{-}17)$$

whereas, the exact rate at θ_{P2} should be (from the exact solution):

$$\omega_{P2} \text{ (exact)} = \frac{V}{H} \cos\theta_{P2} \cos\theta_{R2} \left[\cos\beta_2 \cos\theta_{P2} \right.$$

$$\left. - \sin\theta_{P2} \sin\beta \cos(\alpha_{\beta 2} - \theta_{R2}) \right] . \qquad (2\text{-}18)$$

2.1.3.4.3 Error in Pitch Rate Command - The error in pitch rate at θ_{P2} is: Equation (2-18) - Equation (2-17) and the decimal percent error in LOS rate is:

$$\text{decimal percent } e_{\omega_P}\Big|_{\theta_{P2}} = \frac{\text{Eq. (2-18) - Eq. (2-17)}}{\text{Eq. (2-18)}} .$$

Substituting in the above:

$$\%e_{\omega_P} = \frac{\left\{\left[\cos\beta_2 \cos\theta_{P2} - \sin\theta_{P2} \sin\beta_2 \cos(\alpha_{\beta 2} - \theta_{R2}) \cos(\alpha_{P1} - \theta_{R1})\right]\right.}{\cos\beta_2 \cos\theta_{P2} - \sin\theta_{P2} \sin\beta_2 \cos(\alpha_{\beta 2} - \theta_{R2})}$$

$$- \frac{\left.\frac{\cos\theta_{P2}}{\cos\theta_{P1}} \left[\cos\beta_1 \cos\theta_{P1} - \sin\theta_{P1} \sin\beta_1 \cos(\alpha_{P1} - \theta_{R1})\right]\right\}}{\text{denominator}}$$

The following assumptions are made to estimate the error:

- That $\cos(\alpha_\beta - \theta_R) = 1$ (i.e., worse case)
- That $\beta_2 \simeq {}_1$ which states that the misalignment change between evaluation points is ignorable, which appears sound for small time intervals.

So that: $\% \ e_{\omega_P}$ becomes:

$$\text{decimal } \% \, e_{\omega_P} = \frac{\left[\cos\beta \cos\theta_{P2} - \sin\theta_{P2} \sin\beta\right]}{\cos\beta \cos\theta_{P2} - \sin\theta_{P2} \sin\beta}$$

$$- \frac{\frac{\cos\theta_{P2}}{\cos\theta_{P1}} \left[\cos\beta \cos\theta_{P1} - \sin\theta_{P1} \sin\beta\right]}{\text{denominator}} \qquad (2\text{-}19)$$

$$\text{percent } e_{\omega_P} = \left[\frac{\cos(\theta_{P2} + \beta) - \frac{\cos\theta_{P2}}{\cos\theta_{P1}} \cos(\theta_{P1} + \beta)}{\cos(\theta_{P2} + \beta)} \right] \times 10^2$$

(2-20)

An additional assumption will be made in evaluating the error: that closed loop tracking will terminate at nadir, i.e., $\theta_{P1} = 0$ degrees. This is the optimum pitch angle to terminate track and commence open loop evaluation. At this point $\omega_P = \omega_{P_{max}}$ but $\dot{\omega}_P = 0$ so that the effect of the hold is maximized.

Therefore, Equation (2-20) reduces to:

$$\% \, e_{\omega_P} = \left[\frac{\cos(\theta_{P2} + \beta) - \cos\theta_{P2} \cdot \cos\beta}{\cos\beta} \right] \times 10^2 \qquad (2\text{-}21)$$

From Equation (2-21) it is apparent that the accruing error in pitch rate due to this analog implementation is critically dependent on the initial misalignment vector β. As previously noted, with this candidate instrumentation, the rate generation by updating the command rate through the pitch and roll angles is precise (to the model) if β is zero.

Table 2-7 shows the percent error in pitch rate for increasing slant viewing angle for several initial misalignment angles. It is estimated that $\beta_{max} = 3$ degrees since this is the maximum excursion of the attitude control limit cycle.

Table 2-7
PITCH RATE ERRORS

β:	0.5°	1.0°	1.5°	2.0°	2.5°	3.0°
$\theta_{P2} = 1.0^\circ$ $\% \, e_{\omega_P}$	0.016	0.032	0.047	0.062	0.078	0.093
2.0°	0.031	0.062	0.093	0.123	0.153	0.184
3.0°	0.047	0.093	0.138	0.184	0.229	0.305
5.0°	0.076	0.153	0.229	0.304	0.381	0.457
7.0°	0.108	0.214	0.320	0.426	0.533	0.639
10.0°	0.153	0.304	0.456	0.607	0.759	0.911

2.1.3.4.4 <u>Conclusion on Candidate Analog Instrumentation</u> - It should be emphasized that the percent errors in the LOS rate shown in Table 2-7 are due only to computational error. To perform the evaluation of IMC achieved in this mode the error in instrumentation and the error in photographic interpretation must be included. These sources have been previously discussed; however, the error contributed by the computational technique alone points out the constraint of maintaining a small misalignment angle β. The allowable angle θ_{P2}, which is the difference in pitch angle over which evaluation photographs are taken, is constrained by the percent IMC performance which is desired. From Table 2-8, for small β, it is apparent that θ_{P2} must be only a few degrees at maximum. Table 2-8 gives the time approximate interval for evaluation as a function of θ_{P2}.

Table 2-8
EVALUATION OF θ_{P2}

θ_{P2}	Δt
1^{o}	0.67
2^{o}	1.34
3^{o}	2.01
4^{o}	2.68
5^{o}	3.34

where Δ t has been evaluated for the flat Earth model at the 160 n mi altitude and $\theta_{P1} = 0$ degrees, that is, evaluation begins at nadir.

To maintain β as a small angle, say less than one degree, it may be possible to constrain the cycling of the attitude control system as some predictable function of drift time so that the misalignment angle is passing through zero at the time of nadir. Sophistication of the evaluation techniques and possible modifications to the instrumentation scheme are areas recommended for additional study.

2.2 Analysis of Human Contributions

The underlying rationale for measurement of human contribution is based upon adequate knowledge and measurement of system error and environment. The establishment of a system error budget which includes appropriations for human error in tracking and measurement of results is described in Section 2. 1. The human, in an operational sense, may contribute in varying degrees over a range of dynamic conditions and environmental constraints. It is important to establish the boundaries or limits of human abilities in order to predict human effectiveness, given operational and environmental parameters, in the most efficient and practical manner in space.

The requirements for prediction of human contribution are reflected in the objectives and in the design of the three primary experiments relating to acquisition and tracking of terrestrial and space targets. The basic approach consists of establishing subexperiments, each with its objectives and within-experiment priorities. The three primary experiments will be conducted in parallel in a manner that will ensure an adequate sample of the sighting problems under a range of dynamic and environmental constraints and will sequentially test those aspects of interest established through simulation. Orbital relationships and environmental conditions will be measured in an adequate number of cases in order to predict the level of contribution of man on subsequent operational missions.

The techniques of assessment of human contribution imply measurement of system errors, system performance, and human performance at several levels of complexity. The technique is seen as a building block, each level contributing knowledge of results and some predictive capability on a schedule compatible with the conduct of the experiments. The levels of assessment are seen as ranging from qualitative comment by the observer/experimenter on the experiment to a final correlative experimental analysis which will permit prediction of human performance boundaries under real-world constraints. The measurement and analysis of human contribution in meeting the objectives of the primary IVSS experiments will begin on-board the vehicle with return of data to the experiment control center as quickly as possible. The techniques of measurement and assessment vary in complexity and with respect to the location of the analysis and the types and number of data points necessary for the analysis. Additional descriptions of possible parameters for measurement are included in Section 3.0.

The method of analysis primary for experiment P-2 differs from that primary experiments of P-1 and P-3. This method, described in the P-2 experiment, is required to handle the unique aspects of the space target acquisition and tracking problem which does not lend itself to the design approach of replicating over identical dynamic and environmental conditions. A formal experiment design for experiment P-2 will be formulated during Phase I when dynamic constraints, target availability, and results of preliminary simulation studies can be adequately weighed.

Analysis of results on board the vehicle is recommended for the following reasons:

- The problem of return and recovery of information is minimized
- The experimenter/observer is provided with knowledge of the results
- The data regarding human capabilities in measuring and interpreting photographic data in space is obtained
- The flight crew/experimenter progress is dependent upon first hand knowledge of the situation and results.

However, the method of on-board measurement and analysis does not preclude the final accomplishment of this task on the ground after the data has been recovered. Rather, the final measurement and analysis will provide data regarding human capabilities and reliability in measurement and analysis of complex photographic images in space, while permitting prediction of performance in other laboratory deployments.

The on-board analysis depends upon the processing of the photographic records. A processing technique must be chosen which offers minimal weight penalties and little contribution to toxicity or contamination of the

vehicle atmosphere. The characteristics of possible processes including weight, power, and volume are discussed in Volume III. Flight crew skills required to perform the processing are considered minimal, as this is a routine operation. Toxicity and vehicle atmosphere constraints will be considered in Phase I.

The recording and briefing media of the IVSS have been standardized at 70 mm to minimize the logistics problem, provide a maximum level of interchangeability, and provide for flexibility in display and evaluation techniques. Briefing material, the visual evaluation tracker, the recording cameras, and the on-board image analysis devices are designed to accommodate the 70 mm format.

Table 2-9 is a compilation of probable primary experiments, subexperiments, and parameters of interest requiring control, measurement, or assessment of impact upon total human performance.

It has been recommended that first-order analyses of results be made on-board the vehicle to permit assessment of human contribution in meeting the various experiment objectives and LOS angular rate determination criteria, as well as modification of the sequential design, if required. However, due to the requirements to measure atmospheric and weather conditions, analyses required to establish the limits of human contribution as a function of environmental and other constraints will be accomplished on the ground as follows:

- Measurements of photographic data will be made to establish the following:

  (a) The reliability and precision of the human in acquiring, tracking, and photographing the targets and conditions specified in the sequential experiment design

  (b) The limits of human capability under a spectrum of environmental and mission constraints

  (c) The effectiveness of simulation and training for acquisition, tracking, and on-board analysis

  (d) The reliability and precision of human in-space measurement of photographic data.

- Analyses of photographic data will be made to establish the following:

  (a) The adequacy of human processing, quality judgment, and analysis of photographic data in space

  (b) The human ability to describe and comment upon characteristics of the time-varying visual image

  (c) The human ability to perform "change detection"

Table 2-9
PARAMETERS OF INTERESTS FOR PRIMARY EXPERIMENTS P-1, P-2, AND P-3

FUNCTION CHARACTERISTIC CONSTRAINT	PRIMARY EXPERIMENT P-1 "ACQUISITION AND TRACKING OF PRE-ASSIGNED TARGETS"						PRIMARY EXPERIMENT P-2 "ACQUISITION AND TRACKING OF SPACE TARGETS"				PRIMARY EXPERIMENT P-3 "ACQUISITION AND TRACKING OF TARGETS OF OPPORTUNITY"			
	SUB-EXPERIMENT P1.1	SUB-EXPERIMENT P1.2	SUB-EXPERIMENT P1.3	SUB-EXPERIMENT P1.4	SUB-EXPERIMENT P1.5	SUB-EXPERIMENT P1.6	SUB-EXPERIMENT P2.1	P2.1.1	SUB-EXPERIMENT P2.2	P2.2.1	SUB-EXPERIMENT P3.1	P3.1.1	SUB-EXPERIMENT P3.2	P3.2.1
A SYSTEM CHARACTERISTICS														
• ACQUISITION														
- AUTOMATIC-TARGET PRECISELY KNOWN		✓	✓				✓		✓					
- AUTOMATIC-TARGET IMPRECISELY KNOWN							✓		✓		✓		✓	
- MANUAL-PRIMARY MODE		✓	✓	✓			✓		✓					
- MANUAL-ALTERNATE MODE				✓			✓		✓		✓		✓	
• TRACKING					N/A, ON-BOARD ANALYSIS AND MEASUREMENT OF PHOTOGRAPHIC DATA	A CONTINGENT MAINTENANCE EXPERIMENT TO BE ACCOMPLISHED IF CONDITIONS WARRANT IT	✓	ON-BOARD ANALYSIS PERIOD	✓	ON-BOARD ANALYSIS PERIOD		ON-BOARD ANALYSIS PERIOD		ON-BOARD ANALYSIS PERIOD
- AUTOMATIC-DIGITAL		(AS BASE LINE)					✓		✓					
- AUTO-MANUAL AIDED (DISCRETE ITERATIVE)	ALIGNMENT AND CALIBRATION TASK	✓	✓				✓		✓					
- MANUAL-CONTINUOUS DIGITAL		✓	✓	✓			✓		✓		✓		✓	
- MANUAL-CONTINUOUS ANALOG				✓										
• FILTER SELECTION							✓		✓					
- CONVENTIONAL		✓	✓	✓			✓		✓		✓		✓	
- SELECT 1 OF 2 OTHERS		✓	✓	✓							✓		✓	
• EXPOSURE TIME SELECT							✓		✓					
- AUTOMATIC		✓	✓	✓			✓		✓		✓		✓	
- MANUAL		✓		✓							✓		✓	
• FRAME RATE SELECT											✓		✓	
- 1 TO 4 FRAMES PER SEC		✓	✓	✓			✓		✓		✓		✓	
- CINE - 4 TO 60 FPS		✓	✓	✓			✓		✓		✓		✓	
• FILM TYPE SELECT		✓	✓	✓			✓		✓		✓		✓	
B OPERATOR CONTRIBUTION														
• QUALITY FILTER (PHOTO YES-NO)	N/A	✓				N/A	✓		✓		✓		✓	
• CHARACTERIZE TIME VARYING IMAGE		✓	✓	✓	N/A		✓		✓		✓		✓	
- CHANGE DETECTION		NOT REQUIRED	PRIMARY OBJECTIVE	NOT REQUIRED	✓									
- SUBJECTIVE REPORT		✓	✓	✓	✓		✓		✓		✓		✓	
- PROBABILITY OF SUCCESS		✓	✓	✓	N/A		✓		✓		✓		✓	
• ANALYZE AND MEASURE PHOTOGRAPH		N/A	N/A	N/A										
- MEASURE TO 0.2 % IMC					✓			✓		✓	N/A	✓	N/A	✓
- RAPID SCREEN FOR TYPE					✓							✓		✓
- MEASURE TARGET SIZE					✓			✓		✓		✓		✓
- QUALITY JUDGEMENT					✓						✓	✓		✓
- CHANGE DETECTION					WITH PHOTO									
• COMMENT ON PROGRESS & RESULTS OF EXPERIMENT														
- BEHAVIOR OF PTS-IVSS	ESSENTIAL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
- ENVIRONMENT CONSTRAINTS	DESIRABLE	✓	✓	✓	✓	N/A	✓	✓	✓	✓	✓	✓	✓	✓
- PROBABILITY OF SUCCESS	N/A	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
• CREW TIME REQUIREMENTS														
CREW MEMBER A	1 HR 30 MIN	[illegible] HRS 0 MIN	PART OF P1.2	4 HRS 05 MIN	10 HRS 0 MIN	15 HRS 0 MIN)	2 HRS 40 MIN	3 HRS 20 MIN	0 HR 50 MIN	1 HR 40 MIN	3 HRS 0 MIN	3 HRS 0 MIN	3 HRS 0 MIN	2 HRS 15 MIN
- CREW MEMBER B	1 HR 30 MIN	7 HRS 0 MIN	PART OF P1.2	4 HRS 05 MIN	10 HRS 0 MIN	NONE	2 HRS 40 MIN	3 HRS 20 MIN	0 HR 50 MIN	1 HR 40 MIN	3 HRS 0 MIN	3 HRS 0 MIN	3 HRS 0 MIN	2 HRS 15 MIN
• VISUAL, PERCEPTUAL-MOTOR TESTING														
- COMPENSATORY TRACKING	NOT REQUIRED	DESIRABLE	DESIRABLE	ESSENTIAL	NOT REQUIRED	NOT REQUIRED	ESSENTIAL	NOT REQUIRED	ESSENTIAL	NOT REQUIRED	DESIRABLE	NOT REQUIRED	DESIRABLE	NOT REQUIRED
- BASIC VISUAL CHARACTERISTICS	NOT REQUIRED	ESSENTIAL	ESSENTIAL	ESSENTIAL	NOT REQUIRED	NOT REQUIRED	ESSENTIAL	NOT REQUIRED	ESSENTIAL	NOT REQUIRED	ESSENTIAL	NOT REQUIRED	ESSENTIAL	NOT REQUIRED
• LENGTH OF EXPOSURE TO ORBITAL FLIGHT	OF INTEREST	0-30 DAYS	0 30 DAYS	0 30 DAYS	0 30 DAYS	OF INTEREST	0 30 DAYS	✓	0 30 DAYS	✓	0-30 DAYS	✓	0-30 DAYS	✓
C ENVIRONMENTAL, DYNAMIC, REAL WORLD CONSTRAINTS														
• TARGET TYPE, FIX POINT TYPE	N/A (SELECTED STARS UTILIZED)				NONE REQUIRED (ANALYSIS PERIOD)	NONE REQUIRED		ANALYSIS OF PHOTO AND OTHER DATA		ANALYSIS OF PHOTO AND OTHER DATA		ANALYSIS OF PHOTO DATA		ANALYSIS OF PHOTO DATA
- TEST PATTERN		✓	✓	✓							✓		✓	
- MILITARY COMPLEX		✓	✓	✓							✓			
- OCEAN TARGET		✓	✓	✓									✓	
- NATURAL GEOGRAPHIC		✓		✓							✓			
- CULTURAL TARGETS		✓		✓							✓		✓	
- SPACE TARGETS							✓		✓					
• WEATHER-ENVIRONMENT														
- CLEAR	N/A	✓	✓	✓		N/A	N/A	ANALYSIS PERIOD	N/A	ANALYSIS PERIOD	✓			
- 10-60 % CLOUDS		✓	✓	✓							✓			
- 60-90 % CLOUDS		✓	✓	✓	✓						✓	✓		✓
- 90 % - TOTAL CLOUDS		✓	✓	✓	✓		✓		✓		✓	✓		✓
- HAZE, AEROSOLS, ENVIRONMENT MEASURES	NOT REQUIRED	DESIRABLE	DESIRABLE	ESSENTIAL	NOT REQUIRED	NOT REQUIRED					DESIRABLE		DESIRABLE	
• TIME OF DAY						N/A								
- DAWN - DUSK	✓	✓	✓	✓			✓	ANY TIME	✓	ANY TIME	✓		✓	
- DAYLIGHT		✓	✓	✓			✓	ANY TIME	✓	ANY TIME	✓		✓	
- NIGHT	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓		✓
WITHIN EXP PRIORITY	ESSENTIAL TEST	PRIORITY 1	PRIORITY 3	PRIORITY 2	PRIORITY 4	CONTINGENT EXP	PRIORITY 1		PRIORITY 2		PRIORITY 2		PRIORITY 1	
NO OF SUBJECTS	12	24	10	14	30	(10)	20	20	10	10	20	8	20	6
TIME PER SUBJECT	15.0 MINUTES	35.0 MINUTES	(PART OF P1.2)	35.0 MINUTES	40.0 MINUTES	90.0 MINUTES	16.0 MINUTES	20.0 MINUTES	10.0 MINUTES	20.0 MINUTES	15.0 MINUTES	45.0 MINUTES	15.0 MINUTES	45.0 MINUTES
SPECIAL CONSTRAINTS	NONE	NONE	GROUND CO OPER	NONE	NONE	CONTINGENT EXP	CO OP TGT REQ	NONE	LAUNCH REQ	NONE	GROUND ASSIST	NONE	GROUND CO-OP	NONE
ORBIT POSITION DEPENDENT	YES	YES	YES	YES	NO	NO	YES	NO	YES	NO	YES	NO	YES	NO
TOTAL TIME PER SUBJECT	3 HRS 0 MIN	14 HRS 0 MIN	NONE	8 HRS 10 MIN	20 HRS 0 MIN	15 HRS 0 MIN	5 HRS 20 MIN	6 HRS 40 MIN	1 HR 40 MIN	3 HRS 20 MIN	6 HRS 0 MIN	6 HRS 0 MIN	6 HRS 0 MIN	4 HRS 30 MIN
TOTAL TIME FOR EXPERIMENT			45 HRS 10 MIN			(SAME)	17 HRS 0 MIN				22 HRS 30 MIN			
TOTAL TIME TO COMPLETION	N/A	20 DAYS	20 DAYS	30 DAYS	30 DAYS	N/A	30 DAYS	30 DAYS	30 DAYS	30 DAYS	30 DAYS	30 DAYS	30 DAYS	30 DAYS
REPLICATIONS OF TOTAL EXP	REQUIRED AS CALIB	OVER 3 FLIGHTS	OVER 3 FLIGHTS	OVER 3 FLIGHTS	OVER 3 FLIGHTS	N/A	OVER 3 FLIGHT	OVER 3FLIGHT	OVER 6FLIGHT	OVER 6 FLIGHT	OVER 3 FLIGHT	OVER 3FLIGHT	OVER 3FLIGHT	OVER 3FLIGHT

(d) The effectiveness of training and experience upon analysis of photographic data in space

(e) The quality and content of photographic data.

- Correlative analyses will be made utilizing a conventional factorial analysis with the data pool and space results, measured atmospheric effects, and telemetered data to establish the following:

  (a) Boundaries of human performance over time

  (b) Contribution of environment, dynamics, and other constraints to error variance

  (c) Requirements for subsequent laboratory deployments

  (d) Types and limits of testing for sequential design.

Detailed descriptions of telemetered system parameters and values, operator performance, and other parameters of interest are included in Volume III. Approaches to ground analysis and control of experiments has yet to be established.

2.2.1 Continuity in Measurement and Analysis of Human Contribution

Measurement of human contribution to the complex task of acquisition and tracking of earth and space targets will be accomplished most effectively if conducted on a systematic longitudinal base, with careful attention to the establishment of a data pool. The long periods of training, performance analysis, and operational skills acquisition make it mandatory to measure the potential flight crew member pool in a systematic fashion, establishing a data base for each individual and the group as an entity over the entire period. In this manner, anomalies, histories of skills development, performance limits, criteria for sequential experimental designs for in-space measurements, and information for on-board measurement for purposes of man-calibration, a key requirement, will emerge.

Measurement of human performance during deployment of the laboratory will of necessity be limited to a small number of subjects (probably two) over a month-long period. The best measurement and analysis technique appears to be measurement of within-subject variability, each subject acting as his own control by applying a sequential design, the test parameters of which have been established by simulation studies. However, subsequent ground comparison of results with that of the flight crew data pool by conventional factorial techniques will permit assessment of the human, as well as prediction of performance on subsequent laboratory deployments. Longitudinal measurement of individual and group performance during training, laboratory deployment, and postflight period is

essential, primarily due to the small number of subjects that will be exposed to space flight and the probable severe constraints upon crew time available for experimentation.

A postflight assessment of crew performance must be conducted to establish a data base for determining any changes as the result of orbital flight or experience and as a method of verifying the fidelity and adequacy of simulation hardware and measurement techniques.

A data pool concept and methods of measurement of the flight crew members on a longitudinal base will be outlined during Phase I. Simulation results of Phase I will be applied to the definition of orbital tests that conform to a sequential fractional factorial design, permitting minor modification of experiment objectives during flight as results become known.

3.0 Experimental Procedures Planning

3.1 Introduction

The approach to measurement of human contribution in terms of system and human error sources has been described in Section 2.0. Man's ability to acquire, track, and characterize a variety of terrestrial and space targets must be tested over a spectrum of environmental constraints, dynamic relationships, and other related factors. In addition, human contribution must be defined in specifics as well as in terms of limits of human capabilities, with particular interest in definition of worst case or lower boundary conditions. Thus an approach must be taken which will permit quantification of the impact of environmental constraints, dynamic relationships between target and vehicle, target types, and system modes of operation. The most effective methodology of quantifying human performance under these conditions, some of which can be measured but not controlled, is the application of a design requiring adequate numbers of sets or replications of the sighting problems over a specific time. In this manner human performance can be described at stages during the experiment, and ultimately predicted as a function of the key constraints provided these constraints are measured during the acquisition and tracking tasks, and correlated with the results.

The primary experiments defined in this section are: (1) P-1, "Acquisition and Tracking of Pre-assigned Ground Targets", (2) P-2, "Acquisition and Tracking of Space Targets", and (3) P-3, "Acquisition and Tracking of Targets of Opportunity on Land and on the Oceans". The major objective of these experiments is to determine human contribution to the acquisition and subsequent tracking of targets with line of sight (LOS) rate compatible with precise image velocity determination. The experiments have been designed to measure and quantify human contribution to meeting this objective. However, other unique capabilities of the human will be assessed as well, permitting predictions to be made regarding human abilities across the range of operational and environmental constraints likely to be encountered during future flights.

The primary experiments make maximal use of the flight crew experimenter, who by definition must be a highly qualified photo-optical experimenter to ensure an adequate probability of meeting experiment objectives. Higher-order judgment, reasoning, and interpretive skills of the human are required during the experiments. The judgment of experiment progress and probable outcome, the characterization of the ongoing process

of acquisition and sighting, and the initial precise measurement of the experimental results will be accomplished on board the vehicle. In essence, the crew members will serve as subjects, experimenters, systems engineers, maintainers, data-reduction specialists, and image interpreters, serving at all potential levels of human contribution from system power activation to complex photo interpretation. Careful attention to selection and training is necessary to ensure that the flight crew can function effectively at the desired levels.

An attempt has been made to identify the various levels of human capabilities and potential contribution to meeting the major experiment objectives. The experiment design is intended to measure all levels of contribution in a systematic and controlled manner, such that the type, the reliability, and the limits of contribution of the human will be measured and can be predicted with an acceptable degree of confidence.

It must be emphasized that the design and analysis of in-space experiments is an iterative process, leading from early to final definition by a process of detailed planning, simulation and analysis. The major factor affecting the in-space experiments is of course the requirement to quantify and predict those levels of human contribution which can be established by means other than orbital flight. As simulation studies progress, the design of orbital experiments will change with the goal of increasing efficiency, probability of success, and predictive power, while minimizing the crew time requirements and on-board experimental apparatus necessary to conduct the experiments and analyze results.

IBM recommends that the primary experiments be conducted over a series of MOL deployments. The type of human contribution, at a high level from the very beginning, will be tested with regards to judgmental and interpretitive capabilities once the basic questions regarding human abilities to acquire and track a series of targets under a wide variety of constraints has been established. Thus, the subsequent flights would be more open-ended, or less rigidly controlled, once the necessary replications had been obtained under controlled conditions, permitting the limits of man's acquisition and tracking capabilities to be established.

The impact of the primary experiment objectives, design, and analysis was assessed at intervals by a design review team, to ensure that experiment requirements were reflected in the final system design. Elemental simulations provided necessary data for experiment planning and

system design as well. Subsystem design constraints and trade-off data were discussed with the experiment planner to ensure that the subsystem incorporated the necessary capabilities to conduct the experiments without undue reliability, cost, weight, and power penalties.

Table 3-1 represents a summary of the crew time requirements necessary to conduct Primary Experiments P-1, P-2, and P-3 during the initial deployment of the laboratory. The experiment sets and replications have been determined with attention to the realistic constraints upon the crew, the availability of targets, environmental constraints, and probable laboratory configuration.

3.2 Primary Experiment P-1-'Acquisition and Tracking of Pre-Assigned Ground Target'

Primary Experiment P-1 is reported in a form similar to the MOL Data Book to permit integration of the major primary experiments. Only those items directly related to measurement of human contribution are included, however. The engineering data will be found in Volumes II and III of the IVSS Final Report. Other data relating to selection, training and task descriptions are included in Volume IV, and are referenced where appropriate.

3.2.1 Experiment Objective

The major objective of Experiment P-1 is to assess man's capability to acquire and track pre-assigned ground targets to an accuracy compatible with the requirements for precise image velocity determination. However, an adequate assessment of human capabilities in the above area requires that a set of specific objectives be established. The specific objectives are as follows:

- To assess man's capability to acquire and track pre-assigned terrestrial targets under a wide variety of mission and environmental constraints.
- To assess man's capability to track a pre-assigned ground target with line-of-sight angular rate determination better than 0.2 percent, in several system modes of operation.
- To determine man's utility in selecting exposure time, film type, and filters as a function of target, mission requirements, and environmental constraints.
- To assess human capability to decide whether conditions are appropriate for taking of photographs, hereafter referred to as crew quality judgments.

Table 3-1
SUMMARY OF CREW TIME REQUIREMENTS, PRIMARY EXPERIMENTS
P-1, P-2, and P-3 ------ INITIAL FLIGHT

Experiment/Sub-Experiment	Total No. of Sets	Length Of Set	Crew Member A		Crew Member B		Tot
			Sighting	Analysis	Sighting	Analysis	
P-1 Acquisition and Tracking of Pre-Assigned Ground Targets	80	------	12 hr 35 min	10 hr 0 min	12 hr 35 min	10 hr 0 min	45 h
P-1.1 Alignment Calibration	12	15.0 min	1 hr 30 min	------	1 hr 30 min	------	3 h
P-1.2 Pre-Assigned Targets in Primary Mode	24	35.0 min	7 hr 0 min	------	7 hr 0 min	------	14 h
P-1.3 Change Detection (1)	10	------	------	------	------	------	-
P-1.4 Alternate Modes	14	35.0 min	4 hr 05 min	------	4 hr 05 min	------	8 h
P-1.5 Classification-Measurement	30	40 min	------	10 hr 0 min	------	10 hr 0 min	20 h
P-1.6 Maintenance	(10)	(90.0 min)	------	(15 hrs)	------	------	(15
P-2 Acquisition and Tracing of Space Targets	60	------	3 hr 30 min	5 hrs 0 min	3 hr 30 min	5 hrs 0 min	17 h
P-2.1 Coplanar targets -	20	16.0 min	2 hr 40 min	------	2 hr 40 min	------	5 h
Measurement-Analysis	20	20.0 min	------	3 hr 20 min	------	3 hr 20 min	6 h
P-2.2 Fly-by targets--	10	10.0 min	0 hr 50 min	------	0 hr 50 min	------	1 h
Measurement-Analysis	10	20.0 min	------	1 hr 40 min	------	1 hr 40 min	3 h
P-3 Acquisition and Tracking of Targets of Opportunity	54	------	6 hr 0 min	5 hr 15 min	6 hr 0 min	5 hr 15 min	22
P-3.1 Terrestrial Targets	20	15.0 min	3 hr 0 min	------	3 hr 0 min	------	6
Measurement-Analysis	8	45.0 min	------	3 hr 0 min	------	3 hr 0 min	6
P-3.2 Ocean Targets-	20	15.0 min	3 hr 0 min	------	3 hr 0 min	------	6
Measurement Analysis	6	45.0	------	2 hr 15 min	------	2 hr 15 min	4
Totals	194	26 min avg	22 hr 05 min	20 hr 15 min	22 hr 05 min	20 hr 15 min	84

(1) P-1.3 conducted as integral part of P-1.2 (2) Both crew members qualified as P-1, P-2, P-3 experimenters. (3) Crew m
mainte

Table 3-1
SUMMARY OF CREW TIME REQUIREMENTS, PRIMARY EXPERIMENTS
P-1, P-2, and P-3 ------ INITIAL FLIGHT

-Experiment	Total No. of Sets	Length Of Set	Crew Member A		Crew Member B		Total Time	Remarks
			Sighting	Analysis	Sighting	Analysis		
d Tracking of Ground	80	------	12 hr 35 min	10 hr 0 min	12 hr 35 min	10 hr 0 min	45 hr 10 min	Average task load of 40.0 min/day per crew member (2). Alignment Calibration. Applicable
ent Calibra-	12	15.0 min	1 hr 30 min	------	1 hr 30 min	------	3 hrs 0 min	to P-1, P-2, P-3.
signed Targets ary Mode	24	35.0 min	7 hr 0 min	------	7 hr 0 min	------	14 hr 0 min	Alignment/Calibration
Detection (1)	10	------	------	------	------	------	------	Performed as part of P-1.2.
te Modes	14	35.0 min	4 hr 05 min	------	4 hr 05 min	------	8 hr 10 min	Analysis and measurement of results.
cation- ement	30	40 min	------	10 hr 0 min	------	10 hr 0 min	20 hr 0 min	
ance	(10)	(90.0 min)	------	(15 hrs)	------	------	(15 hrs)	A contingent experiment utilized if conditions warrant it. (3)
d Tracing ts	60	------	3 hr 30 min	5 hrs 0 min	3 hr 30 min	5 hrs 0 min	17 hr 0 min	Average task load of 18.0 min/day for each crew member.
r targets - ement-Analysis	20 20	16.0 min 20.0 min	2 hr 40 min ------	------ 3 hr 20 min	2 hr 40 min ------	------ 3 hr 20 min	5 hr 20 min 6 hr 40 min	
argets-- ement-Analysis	10 10	10.0 min 20.0 min	0 hr 50 min ------	------ 1 hr 40 min	0 hr 50 min ------	------ 1 hr 40 min	1 hr 40 min 3 hr 20 min	
l Tracking Opportunity	54	------	6 hr 0 min	5 hr 15 min	6 hr 0 min	5 hr 15 min	22 hrs 30 min	Average task load of 20.0 min per day per crew member.
rial Targets ement-Analysis	20 8	15.0 min 45.0 min	3 hr 0 min ------	------ 3 hr 0 min	3 hr 0 min ------	------ 3 hr 0 min	6 hr 0 min 6 hr 0 min	
argets- ement Analysis	20 6	15.0 min 45.0	3 hr 0 min ------	------ 2 hr 15 min	3 hr 0 min ------	------ 2 hr 15 min	6 hr 0 min 4 hr 30 min	
	194	26 min avg	22 hr 05 min	20 hr 15 min	22 hr 05 min	20 hr 15 min	84 hr 40 min	

l as integral part of P-1.2 (2) Both crew members qualified as P-1, P-2, P-3 experimenters. (3) Crew member A considered qualifed in maintenance and repair of IVSS.

2

- To determine man's capability, having been trained as a P-1 experimenter, to characterize the time-varying visual image (Verbal descriptions and log entries)
- To assess human capability to detect "change-in-level" of a pre-assigned target, to classify and describe said change, using both the time-varying visual image and photographic analysis.
- To determine the impact of man's ability to acquire and track pre-assigned reference points prior to acquisition and tracking of the pre-assigned target, and the effect upon acquisition and image velocity determination with and without man in the loop.
- To evaluate the capability of a crew member trained as a P-1 experimenter to classify, interpret and measure photographic results in space.
- To assess human visual characteristics and tracking performance as a function of exposure to space flight, for purposes of "Man Calibration" for the IVSS experiments.
- To evaluate man's capability to maintain the IVSS in good working order by alignment, fault isolation, disassembly, and assembly in space.
- To validate and proof-test established human performance criteria related to Experiment P-1, gathered by ground simulation and aircraft flight test.

To meet the objectives of Experiment P-1, a series of six Sub-Experiments have been designed. These are described in Tables 3-2 and 3-3. The contribution to knowledge of human capabilities are identified for each Sub-Experiment in Section 3.2.3. The major contribution of Experiment P-1 is to estaolish the capabilities and limitations of man in the space environment; participating at a variety of levels as a key element of the IVSS.

3.2.2 Description of Experiment P-1

As described in Section 3.2.1, Experiment P-1 is divided into six sub-experiments, designed and sequenced in a manner that will permit human contribution to be assessed in order to meet the experiment objectives. Careful consideration has been given to number of replications, sequencing and priority of sub-experiments, and analysis of system and

Table 3-2
SUBEXPERIMENTS COMPRISING EXPERIMENT P-1
"ACQUISITION AND TRACKING OF PREASSIGNED GROUND TARGETS"

Sub-Experiment Number	Within Experiment Priority	Sub-Experiment Title
Man-Calibration	Note 1	Basic Visual Testing, Perceptual Motor Skills Evaluation
P - 1.1	Note 2	Alignment and Calibration of the Pointing-Tracking Telescope and Recording Camera
P - 1.2	Priority 1	Assessment of Accuracy of Man's Pointing and Man's Contribution to LOS Angular Rate Determination
P - 1.3	Priority 3	Assessment of Man's Capability to Detect "Changes in Level" of Pre-Assigned Ground Targets
P - 1.4	Priority 2	Assessment of Man's Ability to Acquire and Track Pre-Assigned Targets in Alternate IVSS Modes
P - 1.5	Priority 4	Assessment of Man's Capability to Classify and Interpret Photographic Data in Space
P - 1.6	Note 3	Assessment of Man's Capability to Maintain the IVSS in Space

Note 1 - Visual testing and tracking evaluation required for base-line data. To be performed on a fixed schedule.
Note 2 - Must be performed prior to Experiment P-1 and at specified intervals thereafter.
Note 3 - A contingent formal experiment. To be undertaken if mission or subsystem contingencies warrant cancellation of all or part of P-2, P-2, or P-3.

Table 3-3
ASSESSMENT OF HUMAN CONTRIBUTION TO EXPERIMENT P-1
"ACQUISITION AND TRACKING OF GROUND TARGETS"

Level of Incorporation	Type of Contribution	Assessment by Experiment
Level A	On-off, Mode Selection	All P.1.1 through P.1.6
	Monitor sequences	All P.1.1 through P.1.6
	System Power Management	All P.1.1 through P.1.6
	Insert Film, Manual select of Filters, etc.	P.1.2, P.1.3, P.1.4, P.1.5
	Visual acuity-characteristics	Man Calibration
Level B	Perceptual motor tracking	P.1.1, P.12, P.1.3, P.1.4
	Alignment checking	P.1.1
	Drift correction, rate inputs	P.1.1, P.1.2, P.1.3, P.1.4, P.1.5
	Remove and Replace Components	P.1.6
Level C	Isolation of Failures, Repair	P.1.6
	Quality Judgments	P.1.2, P.1.3, P.1.4, P.1.5
	Selection of Exposure Time, Film, Filters, for conditions	P.1.2, P.1.4, P.1.3
	Characterization of Time-Varying Image	P.1.3, P.1.2, P.1.4
	Screening, Interpretation of Photographic Data	P.1.5, P.1.3
	Evaluate Experiment Progress, Results	P.1.2, P.1.3, P.1.4, P.1.5, P.1.6

operator contribution; such that results can be applied to the general case (be generalizable) with an acceptable level of confidence.

Experiment P-1 and its respective sub-experiments are described in this section in summary form. Detailed descriptions are included for each sub-experiment in appropriate sections of this report. The Summary Experiment Definitions include the following: (1) sub-experiment title, (2) specific objectives, (3) crew time requirements, (4) estimated elapsed orbits to completion, (5) equipment requirements, and (6) evaluation methodology.

IBM recommends that both crew members participate in Experiment P-1. The total crew time requirements over a nominal 30-day mission have been estimated at 45 hours, 10 minutes. This would be divided equally among the two crew members at 22 hours, 35 minutes. The breakdown of activities for both crew member is:

	Sighting	Analysis	Total
Crew Member A	12 Hrs. 35 Min.	10 Hrs. 0 Min.	22 Hrs. 35 Min.
Crew Member B	12 Hrs. 35 Min.	10 Hrs. 0 Min.	22 Hrs. 35 Min.
Totals	25 Hrs. 10 Min.	20 Hrs. 0 Min.	45 Hrs. 10 Min.

3.2.3 Summary Experiment Definitions

3.2.3.1 Sub-Experiment - Non-applicable

3.2.3.1.1 Acquisition and Tracking of Pre-Assigned Ground Targets

3.2.3.1.2 Specific Objectives – Assessment of man's contribution to acquisition and tracking of ground targets compatible with line of sight (LOS) angular rate determination better than 0.1 percent.

Assessment of man's contribution to the process of acquiring, tracking, characterizing, and photographing ground targets of opportunity under a wide variety of environmental constraints.

(For a detailed definition of the objectives of Experiment P-1, refer to Section 3.2.1 of this report, "Experiment Objectives")

3.2.3.1.3 Contribution of Results – Detailed and generalizable knowledge will be gained regarding human capabilities in this area.

3.2.3.1.4 Experiment Priority - For IVSS, Priority 1.

3.2.3.1.5 Sub-Experiment Priority - Non-applicable

3.2.3.1.6 Crew Time Requirements

Crew Member A	Total time	22 hrs. 35 min.
Crew Member B	Total time	22 hrs. 35 min.

Note: Assumption made that both crew members are qualified P-1 experimenters.

3.2.3.1.7 Total Number of Data Collection Orbits Required - 80 to 100

3.2.3.1.8 Total Number of Elapsed Orbits to Completion of Experiment - 30 days

3.2.3.1.9 Evaluation Techniques - Error Measurements, Performance Measurements - Note: For a description of the isolation and measurement of error sources, refer to Section 2.0, Volume IV.

System Error Measurements -

- System alignment and calibration records, prior to, during, and after completion of P-1 experiment
- System state variables, at selected points in time
- Characterization of IMU and servo errors
- LOS angular rate over selected time periods during sighting
- Discrete operator and system response

Operator Contribution Measurements -

- Visual characteristics and tracking performance for "Man-Calibration" purposes
- Discrete operator response, system discrete response sampled, stored, transmitted to ground
- Detailed ground examination of photographic results
- Examination of photo records of alignment
- Verbal reporting and log entries by crew-experimenters
- Examination and measurement of selected photographic data by crew member/experimenter, on-board

Total Performance Measurements -

Ground Tracking Net Vehicle Ephemeride Data over time
Photographic Data
Other Measures Characterizing Situation -

On test sites, characterization of atmosphere at time of sighting is highly desirable.

3.2.3.2 Sub-Experiment P-1.1

3.2.3.2.1 Alignment and Calibration of the Recording Camera and Pointing Tracking Telescope (PTS)

3.2.3.2.2 Specific Objectives – To evaluate man's ability to check and verify alignment of the Point-Tracking Scope and Recording Camera in space.

To evaluate man's ability to adjust the PTS, Recording Cameras, and other subsystem elements mechanically and electrically if deemed necessary by himself or ground control.

The results of this Sub-Experiment will provide data regarding man's ability to adjust and calibrate precision photo-optical and servo systems in a space environment.

3.2.3.2.3 Experiment Priority – For IVSS a necessary pre-requisite for experimentation.

3.2.3.2.4 Sub-Experiment Priority - Prior to experimentation and at 48 hour intervals during initial 10 days, modified schedule thereafter.

3.2.3.2.5 Crew Time Requirements[1]

	Per Sub Exp. Set	No. of Sets	Total
Crew Member A	15.0 min	6	1 hr 30 min
Crew Member B	15.0 min	6	1 hr 30 min
Totals		12	3 hrs 0 min

3.2.3.2.6 Total No. of Data Collection Orbits Required - Not applicable.
Orbit Position Dependent - No

3.2.3.2.7 Total Elapsed Orbits to Sub-Experiment Completion - Total mission duration.

3.2.3.2.8 Equipment Requirements - Refer to Volume III for equipment requirements.

3.2.3.2.9 Evaluation Techniques - System error measurements and human performance measurements -

Error Measurements -

- Photographic record of displacement of star image in photographic plane, prior to alignment
- Photographic record of displacement of star image in photographic plane after manual alignment by crew member

1 Both crew members qualified P-1 experimenters.

- Log entry by crewman/experimenter describing visual image at telescope and diffraction pattern and image in calibrating microscope at camera film plane

Refer to Section 2.0 of Volume IV and Volume III for error measurement definitions.

3.2.3.3 Sub-Experiment P-1.2

3.2.3.3.1 Assessment of Accuracy of Man's Pointing and Man's Contribution to Line-of-Sight Angular Rate Determination.

3.2.3.3.2 Specific Objectives - To determine man's ability to acquire and track terrestrial targets compatible with established criteria.

To determine man's utility in selecting exposure, filter, film type, etc., as a function of mission and environmental constraints.

To assess man's ability to judge whether conditions are appropriate for obtaining photographic data (quality-judgements).

To determine man's capabilities in characterizing experimentally significant aspects of the time-varying visual image.

To determine the impact of classes and distribution of prior reference point sightings upon acquisition, tracking, and image velocity determination.

To validate and proof test performance data and techniques established by simulation and flight test.

Results of this Sub-Experiment will provide data regarding human capabilities in acquiring and tracking terrestrial targets.

3.2.3.3.3 Sub-Experiment Priority - Within P-1, priority 1.

3.2.3.3.4 Crew Time Requirements[1]

	Per Sub Exp. Set	No. of Sets	Total
Crew Member A	35.0 min	12	7 hrs. 0 min.
Crew Member B	35.0 min	12	7 hrs. 0 min.
Total		24	14 hrs. 0 min.

3.2.3.3.5 Total No. of Data Collection Orbits Required - 40

3.2.3.3.6 Total Elapsed Orbits to Completion - equivalent to 20 days.

3.2.3.3.7 Orbit Dependent - Most Sighting Cases - Yes

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1 Assumption that both crew members are qualified P-1 experimenters.

3.2.3.3.8 Equipment Requirements - Refer to Volume III for detailed descriptions of the equipment required for P-1.

3.2.3.3.9 Evaluation Techniques - Error and human performance measurements. Note: For a detailed description refer to Section 2.0, Volume IV.

System Error Measurements -

- System alignment - calibration data; prior to, during, and after completion of Sub-Experiment.
- System state variables at intervals during sighting periods.
- Characterization of IMU and servo errors.
- LOS Angular Rates over time of acquisition and tracking.
- Discrete operator control and system response.

Operator Contribution Measurements -

- Visual and performance in tracking for "man-calibration".
- Discrete operator response, discrete system response over time.
- Detailed ground examination of recording camera photographic results over time.
- Examination of photo - other records of alignment.
- Verbal reports, log entries by crewman/experimenter.
- On-board examination-measurement of photographic data by crewman/experimenter.

Total Performance Measurements -
Ground Tracking Net - Vehicle Ephemeride over time
Photographic Results

Other Measures Characterizing Situation -
On specified test sites, at specified times, characterization of atmosphere by use of specially-equipped aircraft.

3.2.3.4 Sub-Experiment P-1.3

3.2.3.4.1 Assessment of Man's Capability To Detect "Changes in Level" of Pre-Assigned Ground Targets, Utilizing The IVSS.

3.2.3.4.2 Specific Objectives - To evaluate human capability to detect "changes in level" or activity of a pre-assigned ground target, to classify change, working with the time-varying visual image and selected photographic data.

To assess the impact of operator task loading, by change detection requirements, upon acquisition and tracking for line-of-sight angular rate determination.

Sub-Experiment results will contribute to body of knowledge regarding man's ability to interpret visual and photographic data, and to extract significant information or changes. The feasibility and utility of conducting this function from space will be assessed.

3.2.3.4.3 Experiment Priority - IVSS - Priority 1 assigned to P-1.

3.2.3.4.4 Sub-Experiment Priority - Priority 2.

3.2.3.4.5 Crew Time Requirements -

	Per Exp. Set	No. of Sets	Total
Crew Member A	(To be conducted with specified ground targets		
Crew Member B	during P-1.2; no time penalty associated with P-1.3)		

3.2.3.4.6 Total No. of Data Collection Orbits Required - 20

3.2.3.4.7 Total Elapsed Orbits To Completion - Estimated 20 days

3.2.3.4.8 Evaluation Techniques - Error and human performance measurements.

System Error Measurement - (Refer to Section 2.1.1)

- Alignment errors, data on alignment corrections.
- Characterization of servo errors, IMU errors.
- System state variables, computation limitations.
- LOS angular rate over time.
- Discrete operator response and discrete system response tagged with time.

Operator Contribution Measurement

- Man calibration, visual testing and tracking performance by Visual Evaluation Tracker (VET).
- Discrete operator response, switch and mode selection sampled to 0.01 second accuracy in time.
- Detailed examination of Recording Camera photographic data.
- Verbal and written entries by crewman/experimenter.
- Examination of photographic data on a sampled basis by experimenter on-board the spacecraft.

Other Total Performance Measures

- Ground Tracking Net data on vehicle ephemeris.

Special Test or Measurement Requirements

- Characterization of atmosphere at time of P-1.3 Sub-Experiment a necessity.
- Control of "ground truth" a necessity for this sub-experiment.

3.2.3.5 Sub-Experiment P-1.4

3.2.3.5.1 Determination of Man's Ability to Acquire and Track Pre-Assigned Ground Targets in Alternate IVSS Modes, For Purposes of Angular Rate Determination

3.2.3.5.2 Specific Objectives - To assess man's capability to acquire and track pre-assigned ground targets without system crosshair-laying assistance.

To assess man's ability to point and to track ground targets with a minimum of system aiding, for purposes of LOS angular rate determination.

To assess man's ability to characterize the time-varying visual image and to evaluate photographic data under these conditions.

This sub-experiment will contribute to knowledge of man's unique ability to assume system functions in alternate modes and will provide data on the capabilities of man in space with minimal system aiding.

3.2.3.5.3 Experiment Priority - IVSS, Priority 1 for P-1.

3.2.3.5.4 Sub-Experiment Priority - within P-1 Priority 3.

3.2.3.5.5 Crew Time Requirements

	Per Exp. Set	No. of Sets	Total Time
Crew Member A	35.0 min	7	4 hrs. 05 min.
Crew Member B	35.0 min	7	4 hrs. 05 min.
Totals		14	8 hrs. 10 min.

3.2.3.5.6 Total No. of Data Collection Orbits Required - 20

3.2.3.5.7 Total Elapsed Orbits to Completion - 320 (20 days)

3.2.3.5.8 Evaluation Techniques

System Error Measurements -

(Identical to those measured in P-1.2)

Operator Contribution Measurements

(Same as those measured in P-1.2)

Total Performance Measures

(Same as P-1.2)

Other Measures

- On specified test sites, at specified times, characterization of atmosphere by special aircraft recommended.

3.2.3.6 Sub-Experiment P-1.5

3.2.3.6.1 Assessment of Human Capability to Classify, Characterize, and Perform Limited Interpretation of Photographic Data In Space.

3.2.3.6.2 Specific Objectives - To assess man's capability, having been qualified as a P-1 Experimenter, to interpret the photographic data in space for purposes of:

- Measuring acquisition and pointing accuracy.
- Measuring line of sight angular rate.
- Characterizing tracking function over time.
- Judging the "quality" of photographic data.
- Estimating resolution and contrast.
- Determing information content of photograph.
- Measuring size and length of objects.

This sub-experiment will contribute valuable knowledge to man's ability to perform as an experimenter in space, characterizing and measuring photographic data for purposes of monitoring the progress of Experiment P-1.

3.2.3.6.3 Experiment Priority - Experiment P-1 assigned priority 1.

3.2.3.6.4 Sub-Experiment Priority - within P-1, Priority 4.

3.2.3.6.5 Crew Time Requirements[1] -

	Per Exp. Set	No. of Sets	Total Time
Crew Member A	40.0 min.	15	10 hrs. 0 min.
Crew Member B	40.0 min.	15	10 hrs. 0 min.
Totals		30	20 hrs. 0 min.

3.2.3.6.6 Total No. of Data Collection Orbits - None

3.2.3.6.7 Total Elapsed Orbits to Completion - 30 days, Orbit-time dependent - No.

3.2.3.6.8 Equipment requirements - Refer to Volume III for equipment requirements.

3.2.3.6.9 Evaluation Techniques

In Orbit Measurement -

- Experimenter measures location of optical crosshair and location of target on photographs.
- Displacement and LOS angles, as well as slant range are used to calculate X-hair error on ground.
- LOS angular errors are characterized.

[1] Both crew members considered qualified P-1 Experimenters.

- Information content and "quality" of photograph are noted and logged or described on tape.
- Size and length of objects is determined.

Ground Measurement

- Photographs are examined by expert experimenters and photo-interpreters.
- Crewman/experimenter performance is compared with results obtained by ground photographic analysis as well as data obtained by telemetry and tracking. Utility of man in the IVSS is determined by comparison of automatic and manual results.

Sub-Experiment P-1.5 will use photographic data obtained by Sub-Experiments P-1.2, P-1.3, and P-1.4. No additional acquisition and tracking of pre-assigned ground targets will be required to obtain data for P-1.5. The time requirements imposed upon the crew will be used for a photographic data analysis and measurement of selected photos, using the timage analysis devices described in Section 5.3.3.

3.2.3.7 Sub-Experiment P-1.6

3.2.3.7.1 Assessment of Man's Capability to Maintain the IVSS in Good Working Order During Extended Space Operations (A mission or system state contingent experiment)

3.2.3.7.2 Specific Objectives - To evaluate man's capability to monitor the working condition of the IVSS.

To assess man's ability to select alternate modes of IVSS operation when dictated by failures.

To assess man's capability to isolate malfunctions to the appropriate level.

To assess human capability to remove, replace and qualify subassemblies or components of the IVSS in space.

To evaluate man's capability to describe system operation in engineering terminology and to recommend changes in design or function, if appropriate.

This sub-experiment will provide data on man's ability to use his intellect and perceptual motor skills to isolate and repair IVSS malfunctions in space. Human contribution as an engineering or technical evaluator of system performance or function will be assessed.

3.2.3.7.3 Experiment Priority - non applicable.

3.2.3.7.4 Sub-Experiment Priority - A contingent experiment, to be conducted after completion of P-1, P-2, and P-3, or if IVSS condition warrants formal maintenance experiments in lieu of those scheduled.

3.2.3.7.5 Crew Time Requirements -

	Per Exp. Set	No. of Sets	Total
Crew Member A[1]	Variable (1 to 4 hrs)	10	Approx. 15 hrs.
Crew Member B	None		

3.2.4 Test and Evaluation Procedures

This section describes the approach to the P-1 Experiment, including the design, number of replications, and error analyses. An experiment of the nature of P-1, the assessment of human contribution to effective use of photo-optical subsystems in space, will be subject to many environmental and mission constraints, as well as real-time contingencies. These considerations suggest a dynamic experiment planning and scheduling approach for the experiments:

- P-1 Acquisition and Tracking of Pre-Assigned Ground Targets
- P-2 Acquisition and Tracking of Space Targets
- P-3 Acquisition and Tracking of Targets of Opportunity on Land and on the Ocean.

3.2.4.1 Dynamic Scheduling

Experiment scheduling and planning by means of a computerized approach has appeared as the most likely solution to efficient handling of a broad spectrum of constraints and requirements imposed upon the vehicle, subsystems, and crew. For Experiments P-1, P-2, and P-3, IBM recommended that the experiment scheduling approach be extended to include quick-response experiment scheduling and decision-making to ensure an acceptable level of experiment efficiency. Experiments of the visual and photo-optical class are highly constrained by orbit and target positions, as well as by weather and environment, to mention a few. The dynamic scheduling approach appears attractive when P-1, P-2, and P-3 are scheduled in a manner which will permit rapid change to meet contingencies. Scheduling of IVSS experiments by means of an IBM-developed EXOTIC-II, with special emphasis upon development of subroutines for target availability, weather-environment, and crew work-rest cycles, is being considered both as an aid to the IVSS Phase I study and as a means for exercising the program with valid data.

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[1] Crew member A considered qualified in maintenance of IVSS.

Maintenance considerations for the IVSS have followed the reasoning that no maintenance experiments will be attempted which will jeopardize completion of the scheduled formal experimentation P-1, P-2, and P-3. Alignment and calibration of the IVSS is considered essential, however, and Sub-Experiment P-1. 1 describes the requirements for this function. To assess human contribution beyond alignment and calibration, and to ensure human capabilities experimentation with the IVSS in the event failures occur which will not permit the completion of the main line of endeavor, a series of contingent formal maintenance experiments are proposed.

It must be emphasized that the contingent formal maintenance experiments go beyond the maintenance normally expected during a nominal 30-day mission. If failures of the IVSS occur, maximum ground assistance will be provided to the crew to effect rapid repair with minimal impact upon the formal experiments. However, if failures occur, which by their nature or by some combination of events, dictate that Formal Experiments P-1, P-2, and P-3 be severly curtailed or abandoned, the contingent maintenance experiment plan would be executed. This experiment is listed as P-1. 1, titled "Assessment of Man's Capability to Maintain the IVSS in Space."

3.2.4.2 Total Number of Tests to be Performed

A series of five Sub-Experiments comprise Experiment P-1, as described in Section 3.2.3. One additional Sub-Experiment is described as a contingent experiment. The total number of test will not include data from this experiment, but rather P-1.6 will be reported separately. Experiment P-1 consists of five sub-experiments consisting of 80 tests or sets of tests. A test is considered an entity in time where crew member/experimenter A or B is occupied with meeting a functional requirement with a ground target or targets; the total time not to exceed 20 minutes.

3.2.4.3 Experimental Parameters to be Varied During Tests

Experimental parameters in Experiment P-1 consist of at least four major classes, namely environmental, such as weather, lighting, season, orbital characteristics, target or reference point parameters, and system mode or capabilities parameters. An adequate assessment of human capabilities requires that these parameters be identified, be assessed regarding their controllability or lack of controllability, and decisions made regarding the degree of controlled variability desired. On the other hand, parameters of significant interest or impact upon human capabilities assessment of an uncontrollable nature, must be handled by an experiment design and replication technique to permit estimation of

their contribution to variability of results or namely, their impact upon man's capability to function with the IVSS in space.

Parameters to be varied or parameters which the variability of must be assessed with respect upon human capabilities are as follows:

- Environmental Parameters - These parameters are assessed by using an adequate number of samples and by scheduling sub-experiment testing at appropriate times during the mission. Specific environmental parameters of interest are:
  - (a) Weather - Clear, 10 to 60 percent clouds, 60 to 90 percent clouds, 90 to 100 percent clouds.
  - (b) Lighting - Incident angle of sun or moonlight
  - (c) Time of Day - Day-night, dawn, dusk
  - (d) Atmospheric characteristics (nominal) - temperature, pressure, humidity.
  - (e) Atmospheric characteristics (special) - Aerosol content, etc.[1]
- Target or Reference Point Characteristics - Target parameters and reference points of at least five general categories will be used. Each category will of course consist of targets or reference points of considerable variability within target class. With the exception of the test targets and the targets used for Sub-Experiment P-1.3, targets will be selected and within target variability handled by an adequate sample of target types and sighting replications. Target types are:
  - (a) Test Patterns
  - (b) Cultural Targets - Nonmilitary
  - (c) Military Complex, large
  - (d) Military Complex, small
  - (e) Geographic - (significant or unique)
- System Parameters to be Varied - System parameters will be varied in a systematic manner to ensure that human contribution can be assessed at several meaningful levels of man-machine interaction, from minimal or no aiding to more complex types of aiding. The IVSS is considered an experimental device, designed expressly to evaluate human performance at several levels, while accurately characterizing not only human error but system errors as well. A consideration of analyses and measurement of error is included elsewhere in

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[1] Use of special aircraft to characterize atmosphere.

this report. At this writing, the mode of system operation has been considered important enough to have the acquisition and pointing Sub-Experiment P-1.2, replicated in P-1.4 but in alternate modes of operation; essentially under conditions of maximum operator participation.

System parameters or modes are:

(a) Primary Mode - Automatic cross hair laying, iterative loop, ephemeris update a growth capability.

(b) Alternate Mode 1 - System tracking with digital loop. No ephemeris update, operator required to contribute rate information.

(c) Alternate Mode 2 - Tracking aiding, human contributes position and rate information, no iterative loop in tracking and pointing of PTS; analog mode.

Superimposed upon the three basic operating modes of the IVSS are: (1) levels and quality of briefing information, (2) prior photographic records, and (3) verbal characterization of target characteristics, etc. These will be handled by an adequate sample under representative conditions.

- Orbital Parameters - Interest has been expressed in evaluating human contribution to acquisition and tracking of pre-assigned ground targets under conditions of 100 to 300 n mi with various eccentricities and orbital inclinations. The effect of these orbital characteristics upon human capabilities might very well be a significant one. However, for purposes of defining Experiment P-1, the experimenter has worked with a nominal circular orbit of 160 n mi with an inclination of 30 to 38 degrees. Availability of landmarks and targets were assessed with these characteristics, and a demonstration of dynamic scheduling would use a subroutine of this nature for fix point availability. A replication of the complete experiment may be called for to assess the impact upon man's capabilities that imposed by orbital characteristics.

3.2.4.4 Preferred Order of Testing

The Sub-Experiments of P-1 are listed in Table 3-2; within experiment priorities have been established. The preferred order of testing or modification of parameters of interest are handled by the priorities and scheduling of the sub-experiments themselves. The experimental scheduling will consist of Experiments P-1, P-2, and P-3 interleaved in time; and modified by contingencies and possible changes in emphasis. However,

a preferred order of testing is implied by the experiment and sub-experiment priority listings in Table 3-2. The exact ordering and scheduling of experiments on a daily basis will be accomplished at a later date.

3.2.5 Target Types And Description

Acquisition and tracking of pre-assigned targets will utilize known cultural, geographic features, and military complexes mostly within the Zone of Interior, but including locations in Australia, Hawaii, and Puerto Rico. Analyses of targets has been limited to date to targets within the area from Hawaii to Puerto Rico. Target types will include the following:

- Test Patterns - At least three test patterns will be required; their locations a function of the particular orbit chosen. Preliminary analyses indicate that test patterns be located in Australia, the western United States (preferably an arid region), and in Puerto Rico or eastern United States.
- Military Complexes - Fifty-five military complexes, ranging from airfields to army installations, have been assessed with regard to availability. time of exposure to optical sighting, etc. These anaylses have permitted estimates to be made of elapsed orbits to completion of experiment P-1. The computer program developed for the target site analysis has been modified as a subroutine for EXOTIC II, an experiment scheduling tool; to cope with orbit and target position constraints.
- Cultural Targets - Significant cultural features such as intersections of long straight lines (interstate highways). cities, and bridges will be used as known reference points, particularly in Earth areas where military complexes are scarce or non-existent. The selection, characterization, and coordinates of the cultural and geographic reference points has yet to be accomplished.

3.2.6 Target Locations

The Landmark Assessment Study printouts will be submitted under separate cover. The study report will describe the condidate target locations by coordinates, as well as characterize their availability for sighting and LOS range as a function of time and orbital path. Several graphic illustrations will describe likely orbits and location of reference points and targets plotted upon a Mercator Projection; and are included in Volume III.

3.2.7 Test Procedures

In Experiment P-1, "Acquisition and Tracking of Pre-assigned Ground Targets," the events on-board the spacecraft will follow a schedule roughly in order of the priority of experiments. Sub-Experiment P-1.1 will be initiated first, and repeated at 48-hour intervals for the first 10 days; with a modified schedule thereafter. Sub-Experiments P-1.2, P-1.3, and P-1.4 will occur in parallel, with type of sighting and systems mode, and "change detection" experiment sets sequenced on the basis of orbit position constraints and environment, particularly weather. Sub-Experiment P-1.5, a non-orbit position dependent case, will be scheduled during periods when sighting data is not being obtained. Table 3-4 illustrates a very preliminary scheduling of sub-experiments; the specific details of which will depend upon orbital characteristics and choice of ground target locations.

3.2.8 Evaluation Procedure

The evaluation criteria established for Experiment P-1 range from measurement of photographic data on records returned to Earth to analysis of system state variables telemetered to ground. The evaluation data, criteria if established, and application to Experiment P-1 and the sub-experiments, is described in Table 3-5. In Section 3.2.3, Summary Experiment Definitions, operator and system evaluation requirements are summarized. Volume III contains descriptions of optical resolution requirments and allowable photo measurement errors. Section 2.1.1 of Volume IV describes system and operator error budgets.

3.2.9 Manning Data (Spacecraft Flight Crew Members)

3.2.9.1 Task Descriptions

Descriptions of the tasks required of the flight crew are included in Section 4.0. Graphic analyses of the tasks are included with particular emphasis upon identification of crew decision points. The alignment and calibration of the PTS and recording camera are discussed in detail. A graphic task analysis of these requirements are included in that section; and will not be repeated here.

Experiment P-1 does not require the attention of more than one crew member at any given time. However, the nature of the experiment requires that the flight crew be trained as P-1 experimenters to ensure a high probability of experiment success. It has been assumed that both members of the flight crew are qualified P-1 experimenters; and that both will participate in equal degrees in the experiment. Experiment time requirements are therefore divided equally. If one crew member participates in P-1, the crew time requirements would double for him.

Table 3-4
SCHEDULING OF P-1 EXPERIMENTS

Days In Orbit

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

Experiment	Schedule	Total Time
P-1.1 "Alignment and Calibration of the PTS and Recording Camera"	Conduct on 48-hr. schedule → | ← Modify schedule based on data →	Approx. 3.0 hrs. 0 min
P-1.2 "Accuracy of Man's Pointing and Contribution to LOS Angular Rate Determination"	← Twenty-four sighting sets based on availability of targets and environmental conditions → | Estimated completion	14 hrs, 0 min
P-1.3 "Assessment of Man's Capability to Perform 'Change Detection' "	← Conduct 10 sets of "change detection" sighting over 20-day period → | Estimated completion	(part of P-1.2)
P-1.4 "Assessment of Man's Ability to Acquire and Track Targets in Alternate Modes"	| ← Conduct 14 sets of sightings based on availability of targets and environment →	8 hrs 0 min
P-1.5 "Assessment of Man's Capability to Classify and Interpret Photographic Data In Space"	← Thirty sessions of measuring, classifying and integrating photographic results →	20 hrs 0 min
P-1.6 "Assessment of Man's Capability to Maintain the IVSS In Space"	Note: A contingent experiment to be initiated if contingencies force cancellation of formal experiments	15 hrs 0 min

Table 3-5
EVALUATION TECHNIQUES AND CRITERIA - OPERATOR CONTRIBUTION
EXPERIMENT P-1 - "ACQUISITION AND TRACKING OF GROUND TARGETS"

Experimental Question	Evaluation Parameter	Evaluation Technique	Criteria (if established)	Remarks
How did man contribute to LOS Angular Rate Determination? a. Under all conditions b. In primary IVSS mode c. In alternate modes d. During "change detection" experiment	Pointing Tracking Scope (PTS) Line of Sight Angular Rate over time	Examine recording camera photographs over specified time interval. Servo line of sight angular rates sampled digitally.	LOS Angular Rate less than 0.2 percent	Hard copy - Recoverable Some on-board measurement Buffer storage transmitted by telemetry.
Did man contribute to overall sighting and pointing accuracy?	PTS crosshair location with respect to target	Measurement of recording camera photographic results. Displacement of crosshair on photos translated to scale equivalent in feet.	Less than 250 feet Measure X-hair to 0.003 inches in X and Y on projector	Optical comparator should permit accurate measurement to 4 microns or less
How valid or accurate was human quality judgment on taking of photographs?	YES-NO responses of human during each sighting task. Operator characterization of change, reports of change, if any.	Correlate YES-NO quality judgment with "quality" and information content of photograph	To be established.	Photo-interpreters to examine "quality", resolution, and information content of photo data.
How consistently and accurately did crew member perform "change detection" on selected targets?		Correlate operator report of change and characterization of change with "ground truth." Examine photographic records taken of site. Compare atmospheric effects with operator performance to determine correlation if any.	Not established.	Characterization of atmosphere desirable. Photo interpreters required for ground analysis.
Was the experimenter capable of processing and classifying photographic data in space?	Log entries and verbal descriptions of selected photographs.	Compare crew member performance on selected photographic data with analyses performed by ground photo interpreter.	Not established.	Refer to Section 2.0 for considerations of on-board measurement.
Characterize the operator's acquisition and tracking performance over time. Has operator performance in space changed from the base-line data? Have visual characteristics changed?	Hand control motions measured over specified time interval during tests. RMS error in tracking on Visual Evaluation Tracker. Man calibration - vision	Error or displacement of cross hair over time - telemetry - photographic. Compare tracking performance in actual experiment and in man calibration test with base-line data.	Equivalent to less than 0.2 percent. Equivalent to less than 0.2 percent.	Discrete mode switching, photo switch, and fix switch sampled, time referenced, and stored on tape.

Table 3-5. Evaluation Techniques and Criteria - Operator Contribution
Experiment P-1 - "Acquisition and Tracking of Ground Targets" (cont)

Experimental Question	Evaluation Parameter	Evaluation Technique	Criteria (if established)	Remarks
What percentage of pre-assigned targets has operator acquired and tracked for criteria?	X-hair location over time Existence of "target" on photographic data. LOS Angular Rate	Examine photographic-telemetered data for: • accuracy of crosshair placement on • acquisition, during tracking with respect to target	> 250 feet > 0.2 percent LOS Angular Rate	Ground analysis by photo interpreters.
For all conditions of P-1 over time	All established parameters	Compare base-line automatic photos with human aided photographs.	None	Both quantitative and qualitative statement of human contribution should be made.
Does crew/experimenter system management, selection of modes, and operation of systems differed significantly from base-line data?	Discrete mode controls	Sample selected discrete IVSS mode controls and discrete system response to 0.01 second.		Digital recording of discrete operator response buffered and telemetered to ground at appropriate time.
Did human have adequate time to perform tasks expected of him?	Operator performance by measuring mode controls, etc. Operator log and commentary.	(Same as above)		
Can the effects of environment, particularly weather be characterized with respect to impact upon human performance?	Performance criteria as a function of atmospheric and lighting constraints.	Ground correlation of atmospheric conditions, other factors, with performance.	Boundaries of human performance for predictive purposes.	Sampling of atmosphere by aircraft a requirement. Test pattern desirable.

Detailed task descriptions of P-1 Test Operations are submitted in graphic task analysis format. Sub-experiments P-1.2 and P-1.4 have identical task requirements, with the system in different modes of operation. These tasks are described in detail in Section 4.0.

3.2.9.2 Work Positions Relative to P-1 Experiment Tasks

The IVSS work station is presently configured as a one-man work station. However, the requirement for the P-1, P-2, and P-3 Experiments to use the data management interface (computer insert and display for example) indicates that a two-position work station be designed to permit common sharing of the experiment management and data management control and display interface. One operator is required at the IVSS work station during the conduct of P-1 experiment. It is recommended that both crew members be qualified P-1 experimenters, sharing the work load for formal experimentation, including alignment and calibration. In sub-experment P-1.6, however, one of the crew members will be qualified to maintain the IVSS, identified at this time as crew member A.

3.2.9.3 Basic Skill Requirements

The fundamental skills required of the crew to conduct and evaluate the progress and results of Experiment P-1 may be termed experimenter skills. The attitudes, training and motivation of the crew must be developed to a level beyond that normally expected of a subject, that equivalent of an assistant experimenter. This is particularly true in the case of characterizing the time-varying visual image, measuring and reporting of sampled data and commenting on the progress of the experiment and operational characteristics of the IVSS in space.

3.2.9.3.1 Alignment and Calibration Skills - Alignment and calibration of the pointing-tracking scope and recording camera requires a basic understanding of the functional characteristics of the IVSS, with particular emphasis upon the design and function of the pointing-tracking scope optics and recording camera. A complete understanding of the purpose of the alignment and calibration and a high proficiency level in conduct of the task is mandatory. This task must be performed quickly and accurately prior to initialization of the formal aspects of Experiment P-1, and at specified intervals thereafter. The consequences of misalignment and the impact upon crew time of this repetitive task demand efficiency and understanding on the part of the crew. It is recommended that both crew members be proficient in this task, but that the task be accomplished by crew member A for the initial 10 days of the experiment and crew member B for the next 10 days.

3.2.9.3.2 Operations Skills - The skill requirements for operations may be described as those equivalent to an assistant P-1 Experimenter. The crew members must be highly motivated, possessed of excellent visual and perceptual-motor skills, and capable of commenting on the progress of the P-1 experiment and the operational characteristics of the IVSS. Specific skill requirements by category are:

- Visual and perceptual skills, experience with target recognition and tracking.
- Development experience and participation in IVSS development flight test, if any.
- Capable of reporting operational characteristics and performance of IVSS in engineering terminology.
- Capable of reporting progress of experiment, making judgments regarding future course of experiment, if necessary.
- Skilled in characterizing and describing the visual aspects of the time-varying PTS image.
- Skilled in detecting "change in level" of specified ground targets.
- Moderate photo interpretive skills, capable of measuring cross hair placement on photographic data and determining accuracy of placement as well as LOS angular rates over specific time interval.
- Skilled operator of IVSS, data management interface, communications subsystem and telemetry.

3.2.9.3.3 Maintenance Skills - In the area of maintenance, two levels of maintenance operations are possible: (1) the conduct of those activities, in addition to alignment and calibration, that are necessary to keep the IVSS in good working order, and (2) the conduct of formal maintenance experiments (P-1.6), conducted on a contingent basis if IVSS status, environmental or mission constraints warrant it.

The skills required for both imply a complete understanding of the IVSS at a functional and detailed flow level, as well as experience and training in failure isolation and disassembly and assembly of components.

A major difference in isolation and repair of operational failures and formal maintenance experimentation is the level of maintenance and the degree of ground assistance. In the operational case, all available assistance would be provided to the crew in isolation and repair of failures, with the explicit goal of re-instating the system to an operational as soon as possible. In the formal maintenance experiment, detailed disassembly and repair, as well as fault isolation and alternate methods of calibration

and alignment would be undertaken with the express goal of validating human capability in maintenance of photo-optical subsystems in space.

3.2.9.3.4 Data Analysis Skill Requirements - The data analysis skill requirements imposed upon the crew may be described in several levels of ascending difficulty and experience with respect to their acquisition. These skills may be grouped into four general categories as follows:

- Operation of data management and photographic measurement apparatus
- Measurement of photographic data in space
- Interpretation of measurement data, both electronically gathered data and photographic results
- Characterization or detailed description of behavior of the subsystem, and reporting of progress of experiment in terms meaningful to the ground experimenters.

The skill requirements implied by the necessity that the crew be qualified experimenters are the most crucial to the success of the experiment. It is desirable that photographic data be analyzed for content and quality and that pointing accuracy and LOS angular rate be measured by photographic means. In addition, the ability to describe the visual image in meaningful terms and to judge the progress of the experiment are requirements that go beyond those normally found in or expected of a typical flight test crew. A preliminary listing of the data analysis skills are as follows:

- Operation of the data management interface, including computer modes, insert and display interface, and tape storage controls
- Operation of the photographic film viewer and photo measuring device
- Capable of reporting characteristics of visual image in meaningful terms
- Skilled in commenting on performance of subsystem in engineering terms
- Skilled experimenters to judge progress of experiment from sampled data.

3.2.9.4 Training Requirements

The skill requirements identified for Experiments P-1, P-2, and P-3 will be refined and translated into crew training requirements. It is desirable that the crew participate in the experimentation and simulation studies related to IVSS, both as a subject and as an experimenter. Periodic involvement of the potential crew members will be required during

development and flight testing of the IVSS. Training requirements will become firm as experiment design and system designs become firm. In general, the training will progress through the following, the duration and phasing of which remains to be established:

- Introduction to purpose and design of Experiments P-1, P-2, and P-3
- Functional and operational characteristics of the IVSS
- Participation as subject and experimenter in IVSS experimental simulation programs
- Participation in developmental design, qualification, and testing of IVSS
- Participation in developmental and experimental flight test operations, if conducted
- Formal extensive training in the operation, conduct, and in-space analysis of IVSS experiments; by means of laboratory and simulation exercises
- Advanced training in the functional characteristics and operational aspects of the IVSS, with emphasis upon fault isolation and repair procedures
- Integrated crew training and experiment procedures training.

The training requirements will be refined as system design and experiment designs for P-1, P-2, and P-3 are established during Phase I.

3.2.9.5 Selection Criteria

It is assumed that the flight crew research pilot pool will possess the visual and perceptual-motor attributes for actual operation of the IVSS during the conduct of P-1, P-2, and P-3. It may be critical that the selection of the crew be based upon a particular skill requirement to conduct IVSS experiments, particularly photo interpretive and aerial observer skills. It is felt that a comprehensive well phased training program will result in the necessary repertoire of skills to ensure a high level of efficiency and a reasonable probability of success. Specific selection criteria remain to be established.

3.2.9.6 Maximum Work Periods

The complex perceptual-motor skills required of the crew member participating in the acquisition and tracking of targets is very demanding. A 30-minute interval of work with the pointing tracking scope is considered a maximum. The analysis of data and measurement of photographs has a recommended maximum work period of 2 hours. Minimum rest period between both work periods is 30 minutes.

3.3 Primary Experiment P-2 - "Acquisition and Tracking of Space Targets"

3.3.1 Approach

The design of Primary Experiment P-2 has considered the essential differences between a simulation laboratory and the space environment. This experiment, dealing with assessment of human contribution to the acquisition and tracking of space targets, is in reality a series of psychophysical measurements. The nature of visual environment, orbital mechanics, and operational environment dictate a series of measurements rather than a controlled presentations of stimulus materials to the observer as is possible in the laboratory.

The essential measurements during Experiment P-2 are as follows: (1) time to acquisition or detection of satellite target and (2), pointing errors over time. These characteristics will be measured by photographic and digital techniques described in Section 2.1 and in Volume III. The error budget for P-2 is described in Section 2.1, which describes the isolation and measurement of error and error variance such that human contribution may be isolated and assessed.

Boundaries will have been established regarding human acquisition and tracking of space targets by means of sophisticated simulation studies, and a data pool of at least 24 subjects. Limits of human capabilities will be predictable with some degree of certainty; permitting an analysis of the contributions of the flight crew based on a limited number of samples; and two subjects, based upon within-subject measures of variance and comparison of results with the data pool.

3.3.2 Considerations Regarding Utilization of One or Two Crew Members

Use of both crew members as participants in Experiment P-2 is recommended. The performance of both crew members can be pooled and compared with the performance of the space crew population as a whole, due to the limited population and remarkable lack of variability in perceptual-motor task performance exhibited by this population after having been trained to criteria. This lack of variability will permit prediction with a level of confidence not ordinarily possible with limited populations.

3.3.3 Analysis of Results of Primary Experiment P-2

Relationships of apparent motion, star field density, and time of acquisition have been established by elemental simulations. These relationships will be studied to some length by means of simulation studies on a longitudinal base, as described in Volume II. These relationships will also serve as the data pool, both on a group basis and for purposes of applying the technique of each subject as his own control.

The acquisition relationships will be plotted for both subjects, and for each subject individually. These relationships will be refined as more measurements are completed. The relationships for acquisition will be compared with those gathered in simulation under equivalent dynamic and environmental constraints, for both the individual involved and for the data pool as a whole.

The tracking characteristics will be measured on board for each of the two observers. This data will be assessed with the primary objective of determining human capability to track compatible with requirements for precise image velocity determination. Primary technique will be photographic recording and measurement, initially on-board, finally on the ground where environmental and dynamic effects will be correlated with performance; thus bounding human performance in P-2.

Experiment P-2 is reported in a form similar to the MOL Data Book for those items related to human functions.

3.3.4 Test Objective

The major objective of Experiment P-2 is to assess man's contribution to space target detection, acquisition, and tracking. A series of specific objectives have been established in order to provide an adequate evaluation of human ability to perform space target acquisition and tracking. The objectives are:

- To evaluate human capability to acquire and track space targets under a representative sample of mission conditions, environmental constraints, subsystem modes, and orbital relationships.
- To assess man's capabilities with regard to characterizing space targets by utilizing the information content in the time-varying image and in photographic data.
- To assess man's contribution in use of the IVSS in several alternate modes of operation to accomplish the specific objectives stated above.
- To evaluate man's capability to acquire and track co-planar targets with the IVSS for purposes of determining his contribution to rendezvous guidance.

To satisfy the objectives of Experiment P-2, two Sub-Experiments have been designed. The Sub-Experiments, P-2.1 titled "Acquisition and Tracking of Targets in Co-Planar Orbits" and P-2.2 "Acquisition and Tracking of Targets in Fly-By Maneuvers For Precise Image Velocity Determination," are shown in Tables 3-6 and 3-7.

Table 3-6
SUB-EXPERIMENTS COMPRISING EXPERIMENT P-2
"ACQUISITION AND TRACKING OF SPACE TARGETS"

Sub-Experiment Number	Within Experiment Priority	Sub-Experiment Title
Man-Calibration	Note 1	Basic Visual Testing, Perceptual Motor Skills Evaluation
P-1.1	Note 2	Alignment and Calibration of the PTS, Recording Cameras, and Vehicle Reference
P-2.1	Priority 1	Acquisition and Tracking of Targets in Co-Planar Orbits
P-2.1.1		Characterization of Targets in Co-Planar Orbits by Use of Visual Image and Photographic Data
P-2.2	Priority 2	Acquisition and Tracking of Targets in Fly-By Maneuvers for Precise Image Velocity Determination
P-2.1.1		Characterization of Targets in Fly-By by Utilizing Time-Varying Visual Image and Photographic Data

Note 1. Visual testing and tracking performance required for man-calibration.
Note 2. To be performed prior to experimentation and at fixed intervals during mission.

Table 3-7
ASSESSMENT OF HUMAN CONTRIBUTION TO EXPERIMENT P-2,
"ACQUISITION AND TRACKING OF SPACE TARGETS"

Level of Incorporation	Type of Contribution	Assessment by Experiment
Level A	Mode Selection, Monitor Sequences, Power Management, Insert Film, etc. Visual acuity	(All) P-2.1, P-2.2 Man Calibration
Level B	Perceptual Motor Tracking Alignment Checks, Drift Correction, Rate Inputs Remove and Replace Components	P-2.1, P-2.2
Level C	Isolation of Failures, Quality Judgments	P-1.6 (Contingent Exp.) P-2.1, P-2.2
	Characterization of Time-Varying Image	P-2.1.1 P-2.2.1
	Evaluate Exp. Progress, Results Measure locations of target, crosshair. Measure and classify targets.	P-2.1, P-2.2

3.3.5 Description of Experiment P-2

Experiment P-2 is divided into two major sub-experiments, each with an analysis requirement associated with it. The sub-experiments relate to acquisition and tracking of targets in co-planar orbits and in fly-by maneuvers. The two major sub-experiments will be conducted in parallel with experiments P-1 and P-3, at times based upon availability and orbital relationships of space targets. The data gained by these sub-experiments will be replicated an adequate number of times under representative conditions to ensure that the results are generalizable to the cases of co-planar and fly-by targets.

Experiment P-2 and its sub-experiments are described in summary form in this section of the report. Summary descriptions include: (1) sub-experiment title, (2) specific objectives, (3) crew time requirements, (4) data collection orbits and elapsed orbits to completion, (5) equipment requirements, and (6) evaluation methodology.

It is desirable that both crew members participate in Experiment P-2. The total crew time requirement over a 30-day mission is estimated at 17 hours, divided equally among the two crew members. The breakdown of activities is:

	Sighting	Analysis	Total
Crew Member A	3 hrs. 30 min.	5 hrs. 0 min.	8 hrs. 30 min.
Crew Member B	3 hrs. 30 min.	5 hrs. 0 min.	8 hrs. 30 min.
Totals	7 hrs. 0 min.	10 hrs. 0 min.	17 hrs. 0 min.

The average daily time requirement for each crew member for sighting and analysis is 18.0 minutes for P-2. However, the availability of targets and their orbital relationships will mean heavier work periods when targets are available for tracking, with intervals during which P-2 will not be conducted.

3.3.6 Summary Experiment Definition

3.3.6.1 Sub-Experiment P-2.1 and P-2.1.1

3.3.6.1.1 P-2.1 - Acquisition and Tracking of Targets in Co-Planar Orbits

P-2.1.1 - Characterization of Targets in Co-Planar Orbits by Use of Visual Image and Photographic Data

3.3.6.1.2 Special Objectives - To assess man's capability in acquisition, tracking and image velocity determination with targets in co-planar orbits.

To evaluate man's ability to characterize the targets in co-planar orbits by using the visual image and photographic results.

To evaluate man's contribution in acquiring and tracking targets in co-planar orbits for purposes of rendezvous.

The results of this sub-experiment will provide data regarding human contribution to optical-photo acquisition and tracking of co-planar targets in orbit.

3.3.6.1.3 Experiment Priority - IVSS Priority 3.

3.3.6.1.4 Sub-Experiment Priority - 1

3.3.6.1.5 Crew Time Requirements[1]

(P-2.1)	Per Exp. Set	No. of Sets	Total
Crew Member A	16.0 min.	10	2 hrs. 40 min.
Crew Member B	16.0 min.	10	2 hrs. 40 min.
Totals		20	5 hrs. 20 min.
(P-2.1.1)			
Crew Member A	20.0 min.	10	3 hrs. 20 min.
Crew Member B	20.0 min.	10	3 hrs. 20 min.
Totals		20	6 hrs. 40 min.

3.3.6.1.6 Total No. of Data Collection Orbits - 30

Orbit position dependent - Yes (both own vehicle and target)

3.3.6.1.7 Total No. of Elapsed Orbits to Completion - 30 days

3.3.6.1.8 Equipment Requirements - Refer to Volume III for P-2 equipment requirements.

3.3.6.1.9 Evaluation Techniques - Error and Human Performance Measurements - Note: For a detailed description refer to Section 2.0, Volume IV.

- System Error Measurements -
  - System alignment - calibration data; prior to, during, and after completion of sub-experiment
  - System state variables at intervals during sighting periods
  - Characterization of IMU and servo errors
  - LOS Angular Rates over time of acquisition and tracking
  - Discrete operator control and system response.
- Operator Contribution Measurements -
  - Visual and performance in tracking for "man calibration"
  - Discrete operator response, discrete system response over time
  - Detailed ground examination of recording camera photographic results over time
  - Examination of photo-other records of alignment
  - Verbal reports, log entries by crewman/experimenter
  - On-board examination - measurement of photographic data by crewman/experimenter.

1 Both crew members qualified P-2 Experimenters.

- Total Performance Measurements -
  Ground Tracking Net - Vehicle Ephemeride over time, Photographic Results.
- Other Measures Characterizing Situation -
  Ground tracking of laboratory and target highly desirable during encounter and tracking by crew member.

3.3.6.2 Sub-Experiment P-2.2 and P-2.2.1

3.3.6.2.1 P-2.2 - Acquisition and Tracking of Targets in Fly-By Maneuvers For Precise Image Velocity Determination

P-2.2.1 - Characterization of Targets in Fly-By Maneuvers by Utilizing The Visual Image and Photographic Data

3.3.6.2.2 Specific Objectives - To evaluate human contribution to acquisition and tracking of targets in Fly-By Orbits with respect to Precise Image Velocity Determination.

To assess man's ability to work with the visual time-varying image of the target and with photographic data to characterize and classify the target.

The results of this experiment will permit analysis of human contribution to acquisition and tracking of targets in fly-by orbits.

3.3.6.2.3 Experiment Priority - IVSS Priority 3

3.3.6.2.4 Sub-Experiment Priority - Priority 2

3.3.6.2.5 Crew Time Requirements

(P-2.2)	Per Exp. Set	No. of Sets	Total
Crew Member A[1]	10.0 min.	5	0 hrs. 50 min.
Crew Member B	10.0 min.	5	0 hrs. 50 min.
Totals		10	1 hrs. 40 min.
(P-2.2.1)			
Crew Member A	20.0 min.	5	1 hrs. 40 min.
Crew Member B	20.0 min.	5	1 hrs. 40 min.
Totals		10	3 hrs. 20 min.

3.3.6.2.6 Total No. of Data Collection Orbits - 10

Orbit position dependent - Yes (own and target vehicle)

3.3.6.2.7 Estimated Elapsed Orbits to Completion - 30 days

3.3.7 Test And Evaluation Procedures

Dynamic Scheduling

The discussion in P-1 regarding the requirements for quick-response computer control of scheduling applies to P-2 as well. See Table 3-3 for scheduling of P-2 Experiments.

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[1] Both crew members qualified P-2 Experimenters.

3.3.8 Total Number of Tests to be Performed

Experiment P-2 consists of two sub-experiments consisting of 30 sets or tests, all of which are orbit position dependent, and 30 periods of data analysis and measurement.

3.3.9 Experimental Parameters to be Varied During Tests

Key parameters to be varied during Experiment P-2 are the following: (1) type of orbital relationship between own vehicle and target, namely co-planar or fly-by maneuver, and (2) system parameters or modes, each involving a specified level of contribution of the man, and an inherent capability of the subsystem.

3.3.10 Target Types and Description

Co-planar target preferably a cooperative launch. A target launched from own vehicle may be satisfactory. (Self-launched vehicle characteristics to be determined.)

Fly-by targets (to be determined).

3.3.11 Data to be Recorded

See Section 2.1, Volume IV, and Volume III for data.

3.3.12 On-Board Data Processing

The functional requirements are the same as those identified for Experiment P-1, except there is an additional function called fly-by targets.

3.3.13 Physical Data Recovery Requirements

3.3.13.1 Photographic

Description of da'a-type and amount -
70 mm Photographs - 6000 Frames

Frequency of recovery -
Recovered at mission end -
Returned by Gemini Reentry Vehicle.
Data Capsule at 6 day interval, if possible.

Security Required -
Classification level at least SECRET.
Results will indicate potential operational capability in space.

3.3.13.2 Records and Logs of Experiment P-2

Description -
Log Books, experiment protocol sheets

Frequency of Recovery -
At end of mission, by Gemini Vehicle.

Table 3-8
SCHEDULING OF P-2 EXPERIMENTS

Experiment / Schedule (Days 1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31)	Total Time
P-2.1 "Acquisition and Tracking of Targets in Co-Planar Orbits"	
← Twenty (20) sets of sightings over 30-day period, if mission and environment permits → (Days 1–31)	7.0 hrs
P-2.1.1 "Characterization of Targets in Co-Planar Orbits"	
← Twenty periods of data analysis → (Days 7–31)	6 hrs 40 min
P-2.2 "Acquisition and Tracking of Targets in Fly-By Maneuvers for Precise Image Velocity Determination"	
← 10 sets of sightings over 30-day period → (Days 1–31)	1 hr 40 min
P-2.2.1 "Characterization of Targets in Fly-By Maneuvers"	
← Ten periods of data analysis → (Days 7–31)	3 hrs 20 min
← Man-Calibration as required during mission → (Days 1–31)	

Note: P-1.6, maintenance experiment - a contingent experiment to be undertaken if mission or subsystem contingencies force cancellation of all or part of P-1, P-2, or P-3.

Security Required -

SECRET

Potential operational capabilities implied.

3.3.13.3 Manning Data

It is recommended that both crew members participate in P-2.

3.3.13.4 Basic Skill Requirements

For a description of skill requirements, refer to Section 3.1

3.3.13.5 Selection Criteria and Training

Refer to Section 3.1 for these requirements

3.3.13.6 Maximum Work Periods

Maximum work periods for Experiment P-2 shall not exceed 15 minutes; during which acquisition and tracking intervals will be of several minutes duration. The very demanding visual requirements indicate short periods of usage. Analysis periods should not exceed 60 minutes.

3.4 Primary Experiment P-3 - "Acquisition and Tracking of Targets of Opportunity on Land and on the Ocean"

3.4.1 Approach

The measurement and defintion of limits of human capability on the acquisition and tracking of "targets of opportunity" is the primary objective of Experiment P-3. The definition of "targets of opportunity" has been established as targets of known characteristics and probable location, the exact locations of which are not known. It is assumed, for the design of P-3 for the initial flight at least, that targets will be briefed, and the locations known to within 10 miles. Targets for the initial deployment will be those not too inherently difficult to locate, of higher contrast with the background and of adequate recognition probability. As data are established regarding human abilities to acquire and track the "easier"targets, those more difficult to locate and perceive will be introduced.

Acquisition and tracking of terrestrial or ground targets will be very similar to that required of the operator during P-1, except that locations are imprecisely known. More attention will be paid during the analysis phase in describing the characteristics of the "targets of opportunity". During the run, the operator will attempt to describe and characterize the time-varying visual image and any inherent difficulties he encounters as a function of dynamics, haze, clouds, or lack of contrast. To accomplish this, the operator must be trained and experienced in this task by means of simulation, by use of developmental flight test, and by operational experience if possible. Training at USAF installations currently engaged in this activity is recommended, the content and duration of which remains to be established during Phase I.

Acquisition and tracking of ocean targets will be conducted in specified areas, with an error volume compatible with the real field of view of the telescope, the scanning dynamics, and the real-time tracking constraints. Ships of all types will be tracked, including ocean going merchant ships, as well as military vessels. The crew members will characterize the real-time visual image, and describe inherent difficulities due to lack of contrast or clouds. On-board analysis of the photographic data is recommended, during which time the crew member attempts to locate, describe, measure, and if possible, classify the target or targets. Provision has been made for on-board measurement and analysis of photographic data of ocean going vessels. The measurement projector and optical comparator will permit measurements of this sort; as well as measurement of line-of-sight angular rate determinations, which are of interest also.

Acquisition and tracking of naval vessels and ocean going vessels of other types will be accomplished in port as well as at sea. Zone of Interior ports such as Galveston and Norfolk are available for tracking. Several areas have been established from Hawaii to Puerto Rico to determine the availability of vessels of known location and type for P-3. These will be included in the target availability program as an aid to experiment scheduling.

Ocean targets are a class of targets for P-1 as well as P-3, the major difference being the accuracy to which the target locations are known. During initial deployment, briefing aids will be provided if possible, to assist the operator in location and classification. Close cooperation of the U.S. Navy is recommended as requirements for ocean target tracking and analysis are refined during Phase I. Training of the potential crew members for this task should be accomplished at Naval installations such as the Naval Reconnaissance and Technical Support Center.

3.4.2 Test Objective

The major experiment objective is to evaluate man's capability to acquire and track land and ocean targets of opportunity. Specific objectives of Experiment P-3 are:

- To evaluate man's capability to scan selected areas of the Earth land mass for purposes of acquiring, tracking, and characterizing targets of opportunity.
- To evaluate man's capability to scan selected ocean areas for purposes of acquiring, tracking, measuring, and classifying ocean-going vessels of all classes.
- To assess man's capability to utilize the time-varying visual image and selected photographic data for purposes of identifying, measuring, and characterizing land targets of opportunity.
- To assess man's capability to use the time-varying visual image and selected photographic data for purposes of identifying and classifying merchant ships, military vessels, and surfaced submarines.

To establish the degree of human contribution and capabilities in this area, and to meet the specific objectives. Experiment P-3 consists of two sub-experiments or tests. Tables 3-9 and 3-10 list the sub-experiments of P-3.

It is important to establish boundaries or limits of human capabilities in the difficult task of ship classification and measurement. Lack of object and background contrast, a major problem in classification, should be measured systematically with cooperation of U.S. Naval vessels, both at sea and in port. The PTS, its resolution capabilities described in Volume III, will be applied to the ship classification problem to measure human abilities under operational constraints.

Table 3-9
SUB-EXPERIMENTS COMPRISING EXPERIMENT P-3
"ACQUISITION AND TRACKING OF TARGETS OF OPPORTUNITY
ON LAND AND ON OCEAN"

Sub-Experiment Number	Within Experiment Priority	Sub-Experiment Title
Man Calibration	Note 1	Basic Visual Testing - Evaluate Perceptual Motor Tracking
P-1.1	Note 2	Alignment and Calibration of the PTS and Recording Camera
P-3.1	Priority 2	Detection, Acquisition, and Tracking of Ground Targets of Opportunity
P-3.1.1		Interpretation, Classification, and Characterization of Ground Targets of Opportunity
P-3.2	Priority 1	Detection, Acquisition, and Tracking of Ocean Targets of Opportunity
P-3.2.1		Classification and Characterization of Ships and Surfaced Submarines

Note 1. Visual testing and tracking performance used as base-line data.
Note 2. To be performed prior to any formal experimentation and at specified intervals thereafter.

Table 3-10
ASSESSMENT OF HUMAN CONTRIBUTION TO EXPERIMENT P-3
"ACQUISITION AND TRACKING OF TARGETS OF OPPORTUNITY
ON LAND AND ON OCEAN"

Level of Incorporation	Type of Operator Contribution	Assessment by Experiment
Level A	Mode Selection, Monitor Systems Status, Sequence of Operation	P-3.1, P-3.2
	Insert Film	P-3.1, P-3.2
	Visual acuity, characteristics	Man Calibration
Level B	Perceptual-motor tracking	P-3.1, P-3.2
	Alignment checking	P-1.1
	Correction of drift,	
	Manual rate inputs	P-3.1, P-3.2
	Remove, replace components	P-1.6 (Contingent Exp.)
Level C	Characterization of Visual Image	P-3.1.1, P-3.2.2
	Interpretation of Phototraphic Data	P-3.1.1, P-3.2.1
	Quality Judgments	P-3.1, P-3.2
	Evaluate progress of experiment	P-3.1, P-3.2
	Measurement of target, crosshair locations	
	Manfunction Isolation, Isolation of Failures	P-1.6 (Contingent Exp.)

3.4.3 Description of Experiment P-3

Experiment P-3 is comprised of two major sub-experiments, acquisition and tracking of land targets and acquisition and tracking ocean targets. Each sub-experiment has associated with it an analysis period whereby the experimenter attempts to characterize and classify the target after having worked with the time-varying visual image and the photographic results. Experiment P-3, will be conducted in parallel with Experiments P-1 and P-2. Specific experiment sets or tests will be interwoven with the other major IVSS experiments based upon orbital characteristics, availability of targets, and environmental constraints, particularly weather. Precise LOS angular rate determination remains a prime area of interest.

Experiment P-3 and its sub-experiments are described in summary form in a manner similar to P-1 and P-2.

Both crew members will participate in Experiment P-3. Total time requirements for the two crew members over a nominal 30-day mission is 22 hours, 30 minutes. A considerable part of the time would be spent in on board measurement and analysis of photographic data. The crew time activities are:

	Sighting	Analysis	Total
Crew Member A	6 hrs. 0 min.	5 hrs. 15 min.	11 hrs. 15 min.
Crew Member B	6 hrs. 0 min.	5 hrs. 15 min.	11 hrs. 15 min.
Totals	12 hrs. 0 min.	10 hrs. 30 min.	22 hrs. 30 min.

The average work load per crew member on a daily basis for conduct and analysis of P-3 is 20.0 minutes.

3.4.4 Summary Experiment Definition

3.4.4.1 Sub-Experiment - N/A

3.4.4.1.1 "Acquisition and Tracking of Targets of Opportunity On Land and On the Oceans"

3.4.4.1.2 Specific Objectives - To assess man's contribution to acquisition and tracking of "targets of opportunity" under a representative sample of mission conditions and environmental constraints.

(For a detailed list of P-3 objectives, refer to Exp. P-3, Test Objective)

3.4.4.1.3 Experiment Priority - Within IVSS, priority 2.

3.4.4.1.4 Crew Time Requirements[1]

Crew Member A	Total Time	11 hrs. 15 min.
Crew Member B	Total Time	11 hrs. 15 min.
	Total	22 hrs. 30 min.

[1] Both crew members considered qualified P-3 experimenters.

3.4.4.1.5 Total Number of Data Collection Orbits Required -

Orbit position dependent - Sighting - Yes
Analysis - No

3.4.4.1.6 Total time to Completion of P-3 Experiment - 30 days estimated.

3.4.4.1.7 Equipment Requirements: Refer to Volume III for equipment requirements.

3.4.4.1.8 Evaluation Techniques - Error Measurements, Performance Measurements - Note: For a description of the isolation and measurement of error sources, refer to Section 2.1, Volume IV.

- System Error Measurements -
  - System alignment and calibration records, prior to, during, and after completion of P-3 Experiment.
  - System state variables, at selected points in time.
  - Characterization of IMU and servo errors.
  - LOS Angular Rate over selected time periods during sighting.
  - Discrete operator and system response.
  - (Refer to Section 5.0, Volume III)
- Operator Contribution Measurements -
  - Visual characteristics and tracking performance for "Man-Calibration" purposes.
  - Discrete operator response, system discrete response sampled, stored, transmitted to ground.
  - Detailed ground examination of photographic results.
  - Examination of photo records of alignment.
  - Verbal reporting and log entries by crew-experimenters.
  - Examination and measurement of selected photographic data by crew member/experimenter.
  - (Refer to Section 5.0, Volume III)
- Total Performance Measurements -
  - Ground Tracking Net Vehicle Ephemeride Data over time. Photographic Data.
- Other Measures Characterizing Situation -
  - On selected test sites and operational targets, characterization of atmosphere at time of sighting is highly desirable.

3.4.4.2 Sub-Experiments P-3.1 and P-3.1.1

3.4.4.2.1 - P-3.1 - Detection, Acquisition and Tracking of Ground Targets of Opportunity

P-3.1.1 - Classification and Characterization of Ground Targets of Opportunity

3.4.4.2.2 Specific Objectives - To evaluate man's capabilities to scan selected areas of Earth's land mass for purposes of acquiring, tracking and determing precise image velocity of targets of opportunity.

To evaluate human capability to classify and describe key aspects of the visual image and photographic data.

To assess operationally the ability of a human to acquire and track ground targets of opportunity under a variety of missions and environmental constraints, compatible with precise image velocity determination.

The results of Sub-Experiments P-3.1 and P-3.1.1 will provide data regarding human contribution to acquisition and tracking of ground targets of opportunity with optical and photo subsystems. Results gathered by simulation and flight test will be validated and proof tested. Limits of human capabilities as a function of orbit and environmental constraints will be established, permitting prediction of human performance on future flights.

3.4.4.2.3 Sub-Experiment Priority - Within P-3, priority 2.

3.4.4.2.4 Crew Time Requirements[1]

(P-3.1)	Per Exp. Set	No. of Sets	Total
Crew Member A	15.0 min.	10	3 hrs. 0 min.
Crew Member B	15.0 min.	10	3 hrs. 0 min.
Totals		20	6 hrs. 0 min.
(P-3.1.1)			
Crew Member A	45.0 min.	4	3 hrs. 0 min.
Crew Member B	45.0 min.	4	3 hrs. 0 min.
Totals		8	6 hrs. 0 min.

3.4.4.2.5 Total Number of Data Collection Orbits - 40

Orbit Position Dependent - P-3.1 - Yes; P-3.1.1 - No.

3.4.4.2.6 Total Number of Orbits to Completion - 520 (est. 20 days)

3.4.4.3 Sub-Experiment P-3.2 and P-3.2.1

3.4.4.3.1 - P-3.2 - Detection, Acquisition and Tracking of Ocean Targets of Opportunity

P-3.2.1 - Classification and Characterization of Ships and Surfaced Submarines

[1] Both crew members qualified P-3 Experimenters.

3.4.4.3.2 Specific Objectives - To evaluate man's capability to scan selected ocean areas for purposes of acquiring, tracking, and determining precise image velocity of ocean-going vessels of all classes.

To assess man's capability to utilize the time-varying visual image and selected photographic data for purposes of identifying, measuring, and classifying merchant ships, military vessels, and surfaced submarines.

To gather operational data on the ability of man to acquire ocean targets of opportunity and to determine precise image velocity requirements under a selected sample of mission and environmental conditions.

Sub-Experiment P-3.2 will validate and proof test results established by simulation and aircraft flight test, while providing data on human contribution to acquisition and image velocity determination of ocean targets of opportunity. Boundaries of man's capabilities will be established for operational constraints.

3.4.4.3.3 Sub-Experiment Priority - within P-3, priority 1.

3.4.4.3.4 Crew Time Requirements[1]

(P-3.2)	Per Exp. Set	No.of Sets	Total
Crew Member A	15.0 min.	10	3 hrs. 0 min.
Crew Member B	15.0 min.	10	3 hrs. 0 min.
Totals		20	6 hrs. 0 min.
(P-3.2.1)			
Crew Member A	45.0 min.	3	2 hrs. 15 min.
Crew Member B	45.0 min.	3	2 hrs. 15 min.
Totals		6	4 hrs. 30 min.

3.4.4.3.5 Total Number of Data Collection Orbits - 40
Orbit position dependent - P-3.2 - Yes; P-3.2.1 - No.

3.4.4.3.6 Total Number of Orbits for Completion - 520 (20 days)

3.4.4.3.7 Equipment Requirements - Refer to Volume III for P-3 equipment requirements.

3.4.4.3.8 Evaluation Techniques - Error and Human Performance Measurements - Note: For a detailed description refer to Section 2.0, Volume IV.

- System Error Measurements -
  - System alignment - calibration data; prior to, during, and after completion of sub-experiment.
  - System state variables at intervals during sighting periods.

---

1 Both crew members qualified P-3 Experimenters.

Characterization of IMU and servo errors.

LOS Angular Rates over time of acquisition and tracking.

Discrete operator control and system response.

(Refer to Section 5.0, Volume III)

- Operator Contribution Measurements -

  Visual and performance in tracking for "man calibration".

  Discrete operator response, discrete system response over time.

  Detailed ground examination of recording camera photographic results over time.

  Examination of photo-other records of alignment.

  Verbal reports, log entries by crew man/experimenter.

  On-board examination - measurement of photographic data by crewman/experimenter.

  (Refer to Section 5.0, Volume III)

- Total Performance Measurements -

  Ground Tracking Net - Vehicle Ephemeride over time, Photographic Results.

- Other Measures Characterizing Situation -

  On specified best sites, at specified times, characterization of atmosphere by use of specially equipped aircraft.

3.4.5 Test and Evaluation Procedures

Comments regarding the requirements for dynamic scheduling of P-1, P-2, and P-3 are included in Experiment P-1. See Table 3-11 for Experiment P-3 schedule.

3.4.6 Total Number Of Tests to be Performed

Experiment P-3 consists of 54 sets of tests in two basic sub-experiments. Of these 40 sets or sighting situations are orbit position dependent.

3.4.7 Experimental Parameters To Be Varied During Tests

Parameters to be varied during Experiment P-3 include: (1) type of target of opportunity, land or sea, (2) class of target type; land, five types, and ocean, three types, and (3) system mode of operation, primary or one of two alternate modes.

3.4.8 Target Types And Descriptions

Land target types are identical to those described in Experiment P-1.

Ocean target types are: (1) military vessels, large and medium, (2) merchant vessels, and (3) surfaced submarines.

3.4.9 Target Locations

Four target location areas for ocean targets were selected and are described in the IVSS Data Book.

Table 3-11
SCHEDULING OF P-3 EXPERIMENTS

1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31	Total Time
P-3.1 "Detection, Acquisition, Tracking Targets of Opportunity (Ground)"	
Twenty sets of sightings, over 30 days, based on availability of targets and environmental conditions	6 hrs. 0 min.
P-3.1.1 "Interpretation, Characterization of Ground Target of Opportunity Using Visual Image and Photos"	
Eight sets of 45 minutes duration, non-orbit dependent periods, as appropriate	6 hrs. 0 min.
P-3.2 "Detection, Acquisition, and Tracking of Ocean Targets of Opportunity"	
Twenty sets of sightings over 30 days, depending on availability of ground targets and weather	6 hrs. 0 min.
P-3.2.1 "Classification and Characterization of Ships and Surfaced Submarines"	
Six sessions of characterizing and classifying ocean targets - non-orbit position dependent	
Man-calibration as required during mission	4 hrs. 30 min

Note: P-1.6, a contingent formal maintenance experiment, will be undertaken if contingencies warrant cancellation of P-1, P-2, or P-3 or some part thereof.

3.4.10 Evaluation Procedure

(Identical to that described for Experiment P-1)

3.4.11 Physical Data Recovery Requirements

3.4.11.1 Photographic

Description - data type and amount

70 mm photographs, approximately 8000 frames.

Frequency of recovery -

At end of mission

Recovery by Gemini Vehicle

Required Security -

SECRET

Operational capability implied.

3.4.11.2 Records and Logs of Experiment P-3

Description -

Log Books, experiment protocol

Frequency of Recovery -

End of mission by Gemini Vehicle

Required Security -

SECRET

Operational projected capability implied.

3.4.11.3 Manning Data

Both crew members will participate in P-3.

3.4.11.4 Basic Skill Requirements - Selection and Training

Refer to Section 3.1, Volume IV

3.4.11.5 Maximum Work Periods

Maximum work periods with the PTS shall not exceed 15 minutes. Actual continued visual and perceptual use of the PTS will be of 1 to 3 minutes duration, with rest intervals of several minutes. Analysis of photos and briefing should not exceed 60 minutes.

3.4.12 Target of Opportunity Search Patterns

Targets of opportunity are characterized by the fact that the area of uncertainty of their locations is greater than the field of view available at a magnification sufficient to permit discrimination by the IVSS observer. Consequently, the PTS must be advanced over the area of uncertainty in some search or scanning pattern. These patterns may be manually controlled or exercised automatically by the IVSS computer in accordance with programs provided. In the latter case, override by the observer is permitted.

Two search patterns, the boustrophedon or raster scan, and the Archimedes spiral were investigated during the present IVSS study. An analytical exposition of these scan patterns is provided in summary form in Section 3.6.

The boustrophedon scan would be particularly valuable in the case where the target may be located anywhere in the area of uncertainty with uniform probability. The spiral scan is also useful in this situation. However, it is particularly valuable in cases in which the target has a maximally probable location at a point, with a decreasing probability of location radially outward from this point. This has the important application to the case of locating a ship which is being tracked. The point of maximum probability, in this case, is the expected position of the ship.

The boustrophedon scan was assumed in the Target of Opportunity Procedure Analytical Simulation Investigation, described in Section 2.0. The procedures described are applicable to other scanning patterns, as well. Reprogramming of the scan will permit the flight crew to assess and select particular patterns for application in space.

3.5 Power Profile of Experiments

Three typical power profiles for three IVSS experiments are shown in Figures 3-1, 3-2, and 3-3. During use of the PTS, on a typical sighting set, it was assumed the servos would require peak power during initial positioning and sighting on the first target, after which the power required for tracking would fall back to an average value. During positioning of the PTS for subsequent targets, the PTS would require approximately 300 watts above the average value for the faster slewing rates.

Sighting on targets of opportunity, with the lengthly search times, requires the additional 300 watts for a significantly longer period of time, as shown in Figure 3-2.

The photo measurement and analysis period should result in the steady power profile shown because of the few IVSS equipments involved. It should be noted that all power profiles given are indicative of power requirements (including regulation) for only the IVSS experiment equipment, and must be integrated with other MOL power requirements occurring during the experiment period for an overall vehicle power profile summary.

The overall power requirements of the system, including regulation, are included in Section 5.0 of Volume III.

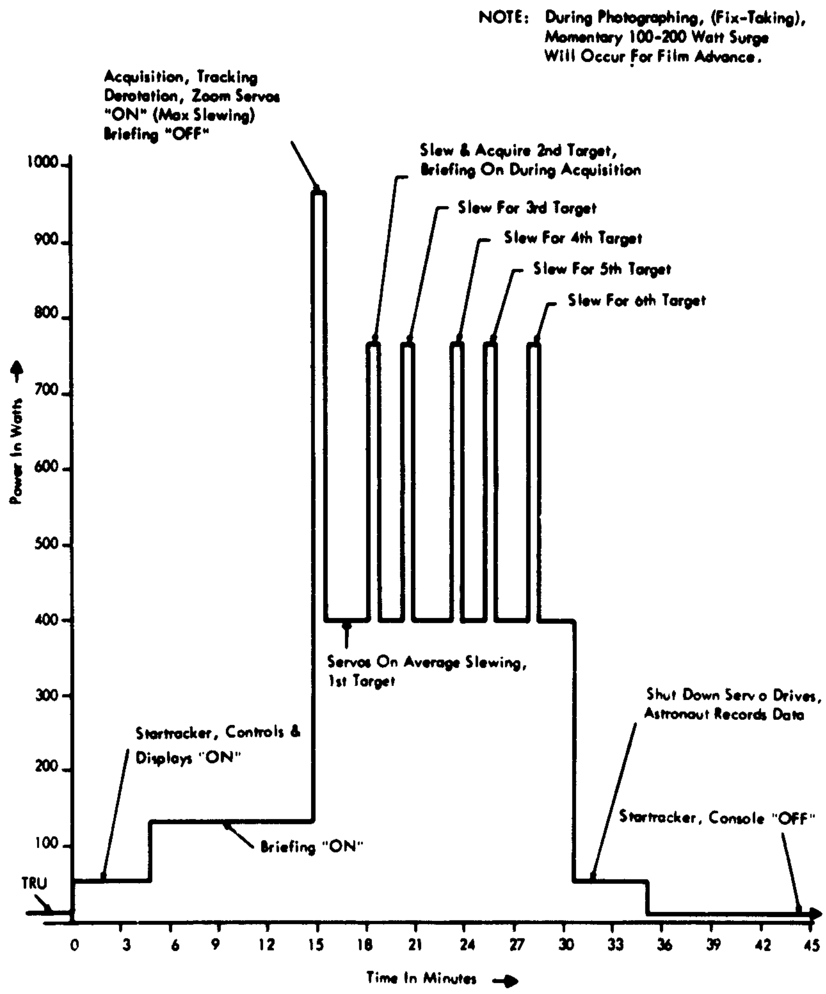


Figure 3-1. Power Profile, Typcial Sighting Set, Six Targets

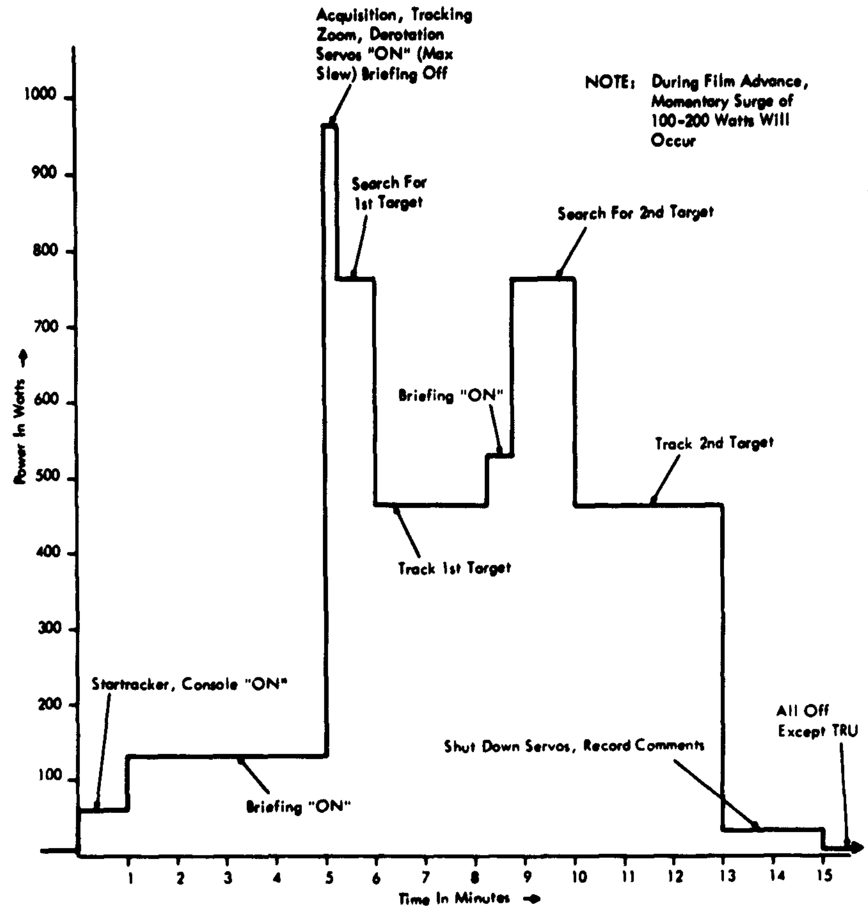


Figure 3-2. Power Profile, Typical Sighting On Targets Of Opportunity, Two Targets

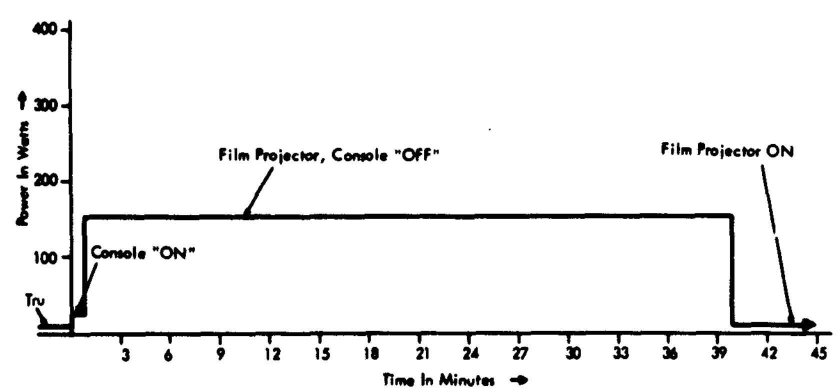


Figure 3-3. Power Profile, Typical Photo Data Measurement And Analysis Period

3.6 Experiment Scheduling

It is well recognized that scheduling of experiments for the laboratory remains as a major task. Efforts to date to schedule experiments with EXOTIC II, based upon a computer methodology, have resulted in reasonable success. Availability of targets as a function of orbital parameters and day-night cycles has been used as a scheduling constraint. Using data gathered by a computer analysis of the availability of 55 targets in the Zone of Interior, estimates were made of the crew time required to complete experiments P-1, P-2, and P-3. These are reported in Section 3.0 of this volume. The analysis of the availability of targets is included in the Data Book supplement to the IVSS Final Report.

No firm scheduling of IVSS experiments is reported in this volume, although during the study several schedules were compiled to arrive at crew time requirements for sighting and analysis which were compatible with the probable work-rest cycle and total crew time availability, while meeting the requirements for sampling an adequate number of targets under enough environmental and dynamic constraints. In this context, the crew time requirements for sighting and analysis are considered minimal for a nominal 30-day initial deployment of the laboratory, and were arrived at by careful consideration of the design and real-world availability of targets. The primary experiments are described in Section 3.0, including the estimates of total crew time required to conduct the experiments and sub-experiments, the specific daily scheduling of which remains to be accomplished during Phase I.

A coordinated approach to experiment scheduling and integration is recommended during Phase I, during which the target requirements, orbital dynamics, experiment design, and flight crew segment requirements are considered not only for P-1, P-2, and P-3, but for all experiments using the IVSS.

Primary Experiments P-1, P-2, and P-3 are of a nature that ground experiment support and analysis is highly desirable. It is entirely reasonable that additional primary experiments will be grouped with those mentioned above, but the requirements stated herein are for support of P-1, P-2, and P-3 only. It has been assumed that an experimental control function will be established, which will provide the necessary data and decisions to support the mission control, operating at a higher level. A reasonable hierachy of decision-making and command functions must be allocated to both experiment and mission control, to ensure timely and efficient attainment of both experimental and mission objectives, with crew safety and health considerations of primary importance.

The experimental control of P-1, P-2, P-3 Experiments will require a team of eight persons, working three shifts, for the entire mission; other related primary experiments could also be handled by this group. The group will be responsible for the following primary functions:

- Monitor progress of scheduled Primary Experiments P-1, P-2 and P-3
- Examine telemetered data and related data for purposes of determining experiment results
- Examine hard copy when available (desirable at mission time of 6 days, 12 days, 18 days, with final return on Gemini vehicle)
- Provide instructions, qualification, and technical assistance to the on-board experimenter(s) on a demand basis
  (Note: Engineering contingency analysis is considered a function of Mission Control)
- Provide superiors in experiment control, or mission control with data to support decision-making, when required
- Request modifications to schedule or to mission due to experimental results, contingencies, or other constraints
  (Note: Command or control level remains to be established between experiment and mission control)
- When required, examine performance history and anomaly files for comparisons of crew in-space performance
- Provide capability to re-schedule on a several orbit turn-around, any or all of the three primary experiments.

It would be desirable to locate the Experiment Control Center in the same building as the Mission Control to facilitate discussion, but it is not mandatory. A detailed analysis of the experiment support requirements will be undertaken during Phase I, including integration of functions for other experiments using the IVSS.

4.0 Functions of Man

4.1 Approach

In general, the approach used in delineating the functions of man was an attempt to complement the experimental program objectives and subsystem design constraints. The evolution of the experiments, equipment requirements, human functions, and man/machine interface proceeded parallel with consequent compromises and tradeoffs made as necessary during the analysis. Each requirement was looked at in depth, repeatedly, with the final outcome being Figure 5-1 of the IVSS Panel Layout included in Section 5.0, "Human Engineering Considerations".

4.2 Functional and Task Analysis

The first step in the functional analysis was to lay out all functions and related tasks required in an image velocity sensing system in the sequence in which they would be performed. No attempt was made to define the man/machine interface at this point. Figure 4-1, "Flow of Functions Required for IVSS Experimentation and Operation", shows the results of this portion of the analysis. The next step was to look at the various functions from the point of view of criticality, separating those functions essential to the IVSS and those which tend to be mostly a support to the overall effectiveness of the experiment or test. An analysis of each function was then made. In performing this tradeoff, the following points were kept in mind: minimize equipment requirements (especially redundancy), minimize manpower requirements, and especially try to require only one operator on duty at a given time to perform a given set of experiments. The basic results of this portion of the study is shown in Figure 4-2, "Allocation of Functional Responsibilities Between Stations". Basically, the reasoning behind a two-station console is as follows: Since there are experiments other than the IVSS experiments (P-1, P-2, P-3) to be included in the MOL program, plus the fact that at least two astronauts will be used, and since the whole system is really only in the conceptual stage at this point, it seemed unreasonable to have a highly integrated console physically wrapped around one operator. By having a two-station console broken out functionally, as shown in Figure 4-2, it is possible to have either station in use separately or simultaneously. Also, the equipment incorporated at Station II represent functional requirements to support P-1, P-2, and P-3, and will in all probability be included as functions of the integrated displays developed to satisfy the total experimental program.

The general approach used in the study was to proceed from the macro level to the micro level of description of human functions. Clearly, by the

very nature of pre-Phase I it would be impossible to have a complete and firm answer to all questions. However, it was possible to determine, on a preliminary basis, the structure of each function and the feasibility of having it performed by the human. The results of such an analysis are contained in Figure 4-3, "Task Flow for Briefing Function--Station I" through Figure 4-16, "Task Flow for Projection Screen Operation--Station II". In many instances specific tasks are included, but they are included for experimental verification. For example, there is still some question with regard to manual control of filters and exposures. One immediate problem, of course, is the question of training. How expert a photographer will (or must) the astronauts be? Experience with filters and exposures is extremely critical. There are advantages to be gained by the incorporation of manual selection, but misuse by a naive operator could certainly be disastrous. Another, similar area, discussed in Section 3.0 of this volume, "Experiment Procedures Planning", is the ability of the operator to make judgements about not taking pictures when conditions are below minimum or optimum (Quality Filtering). However, on all three counts, continued study is required to determine which approach to take in incorporating the human in the experimental subsystem. Without sufficient evidence it is deemed foolhardy to incorporate such tasks on an operational basis. However, they are included on an experimental basis so that a possible in-orbit determination can be made as to whether such tasks should actually be assigned as functions of man in an operational system.

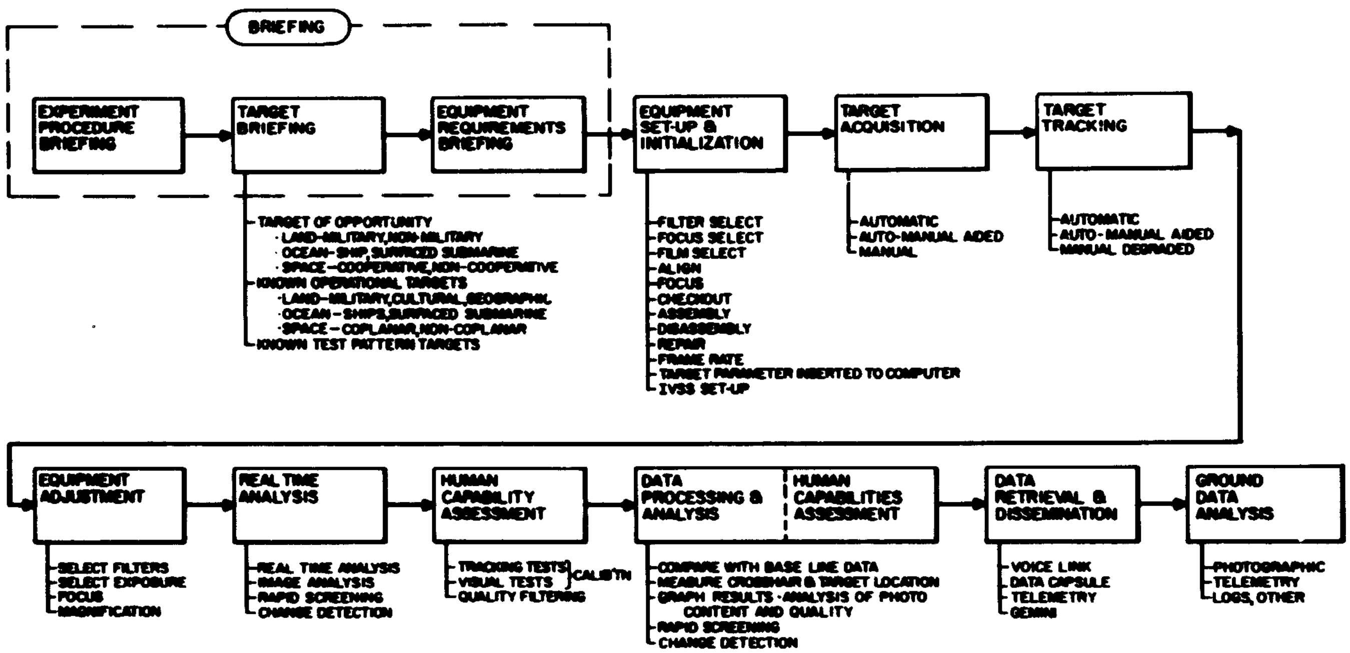


Figure 4-1 Flow of Functions Required for IVSS Experimentation and Operation

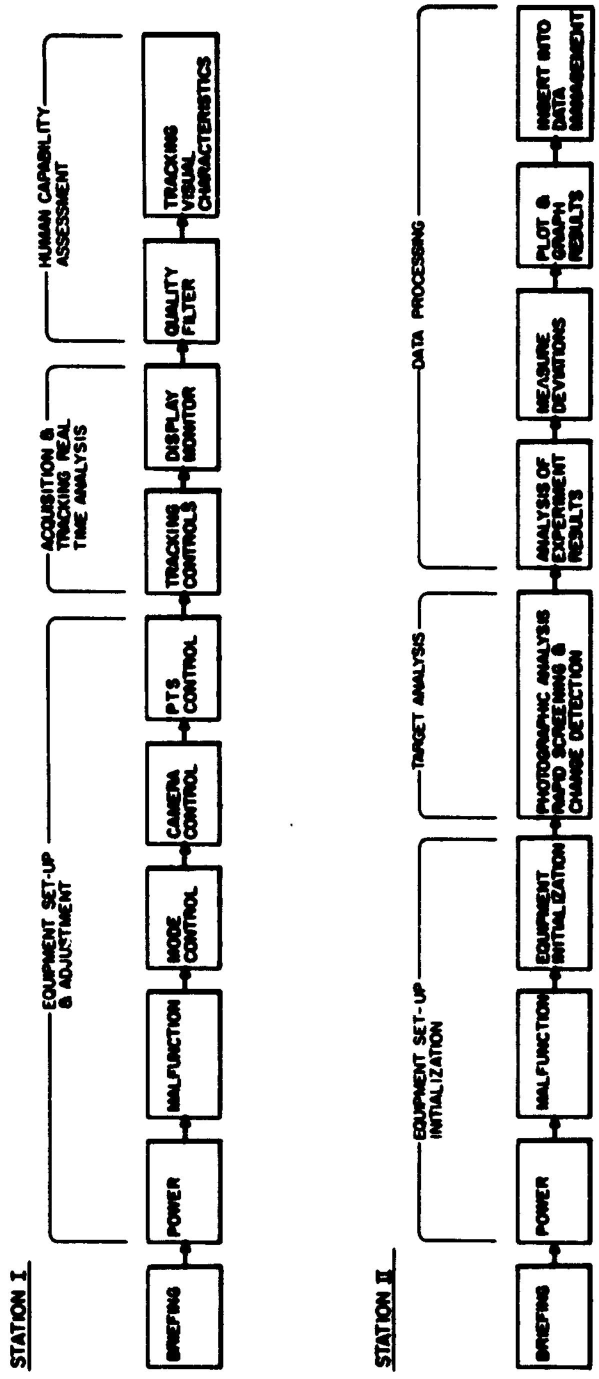


Figure 4-2. Allocation of Functional Responsibilities Between Stations

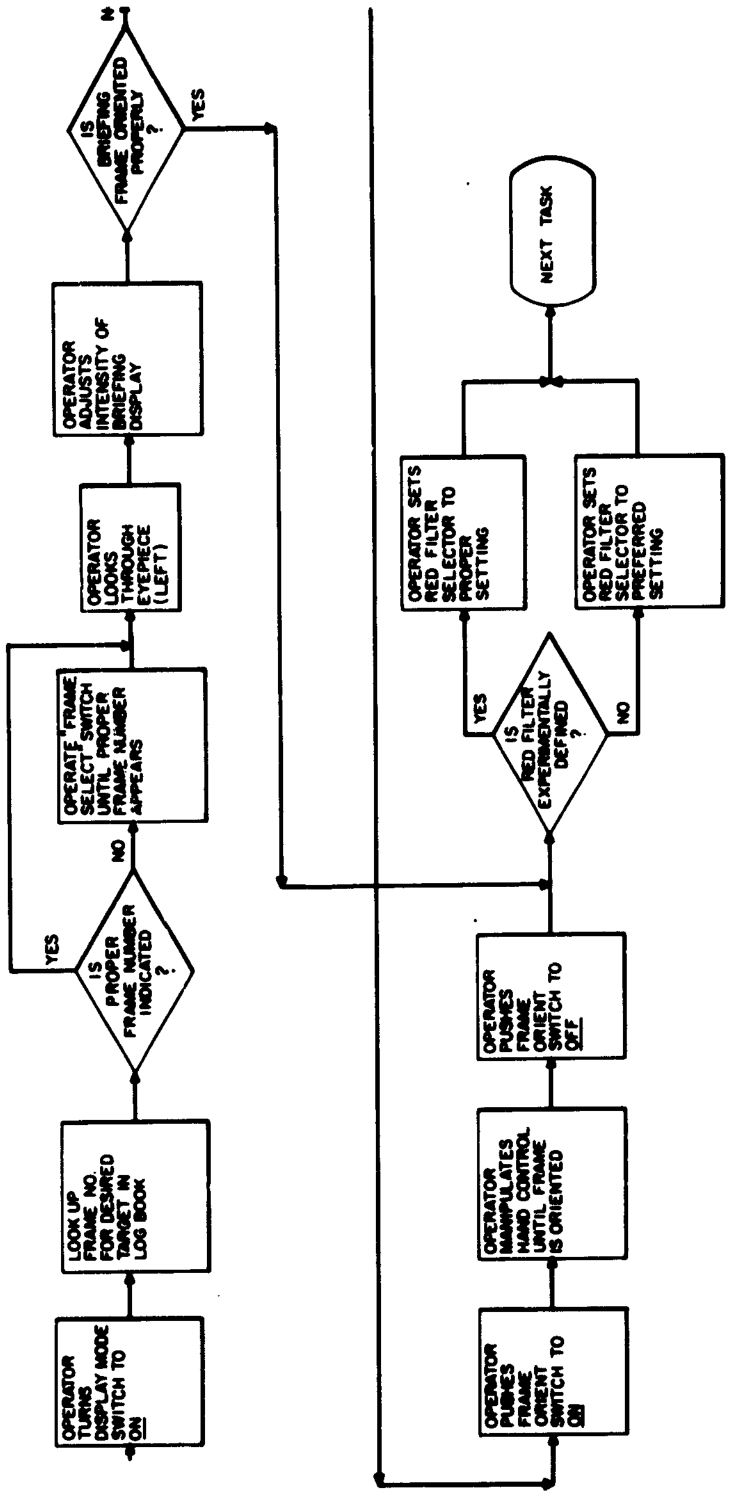


Figure 4-3. Task Flow for Briefing Function-Station I

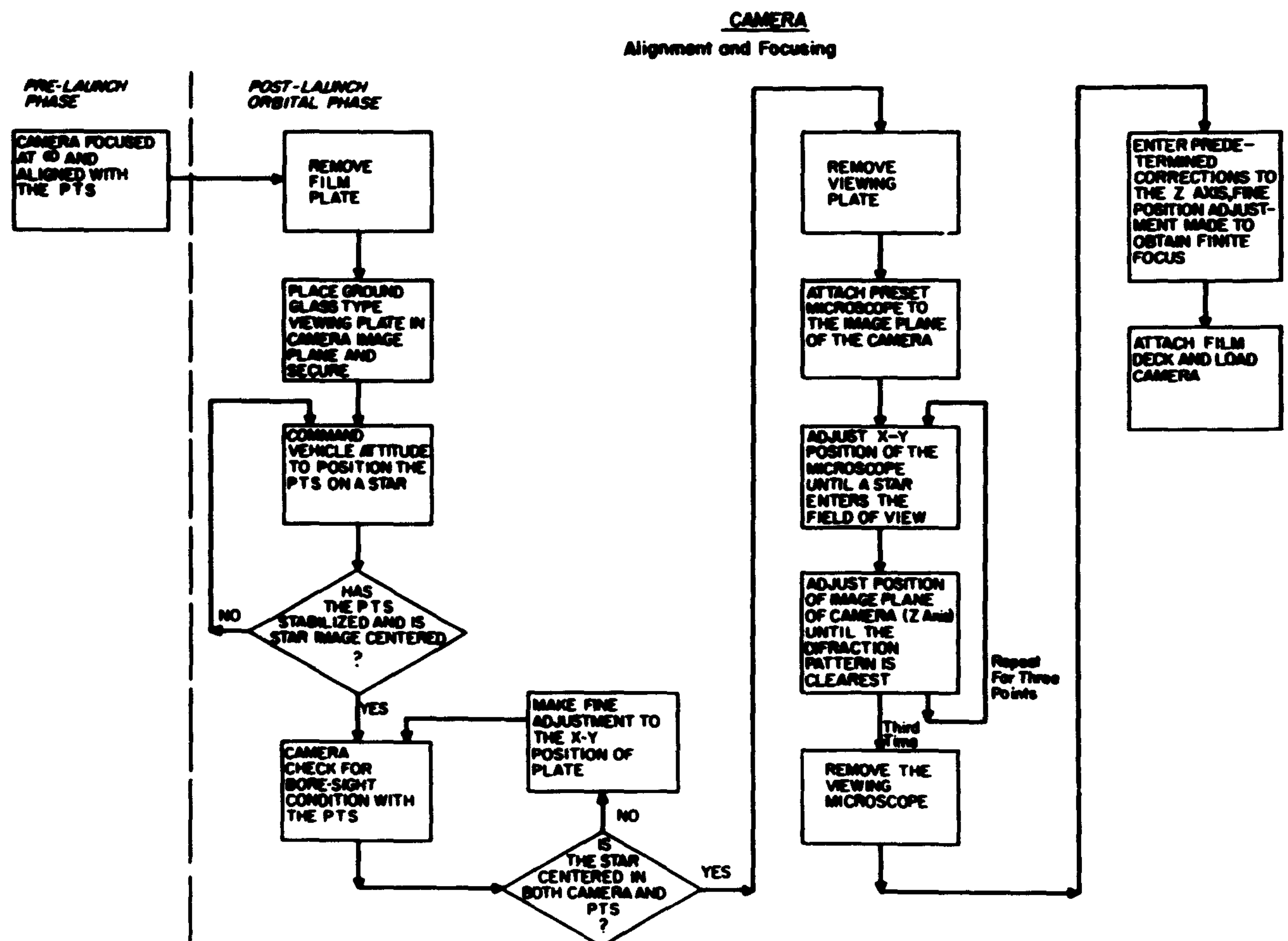


Figure 4-4. Camera Alignment and Focusing (Both Cameras)

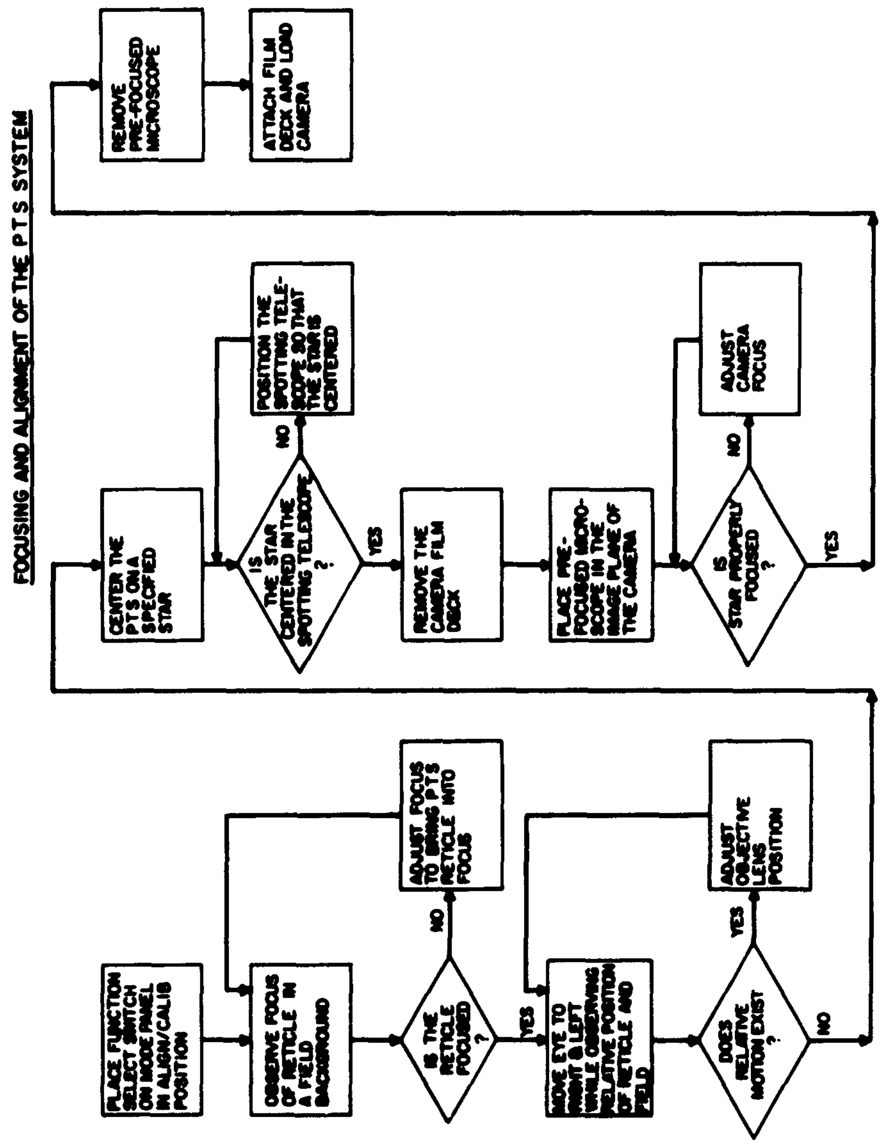


Figure 4-5. Focusing and Alignment of the PTS

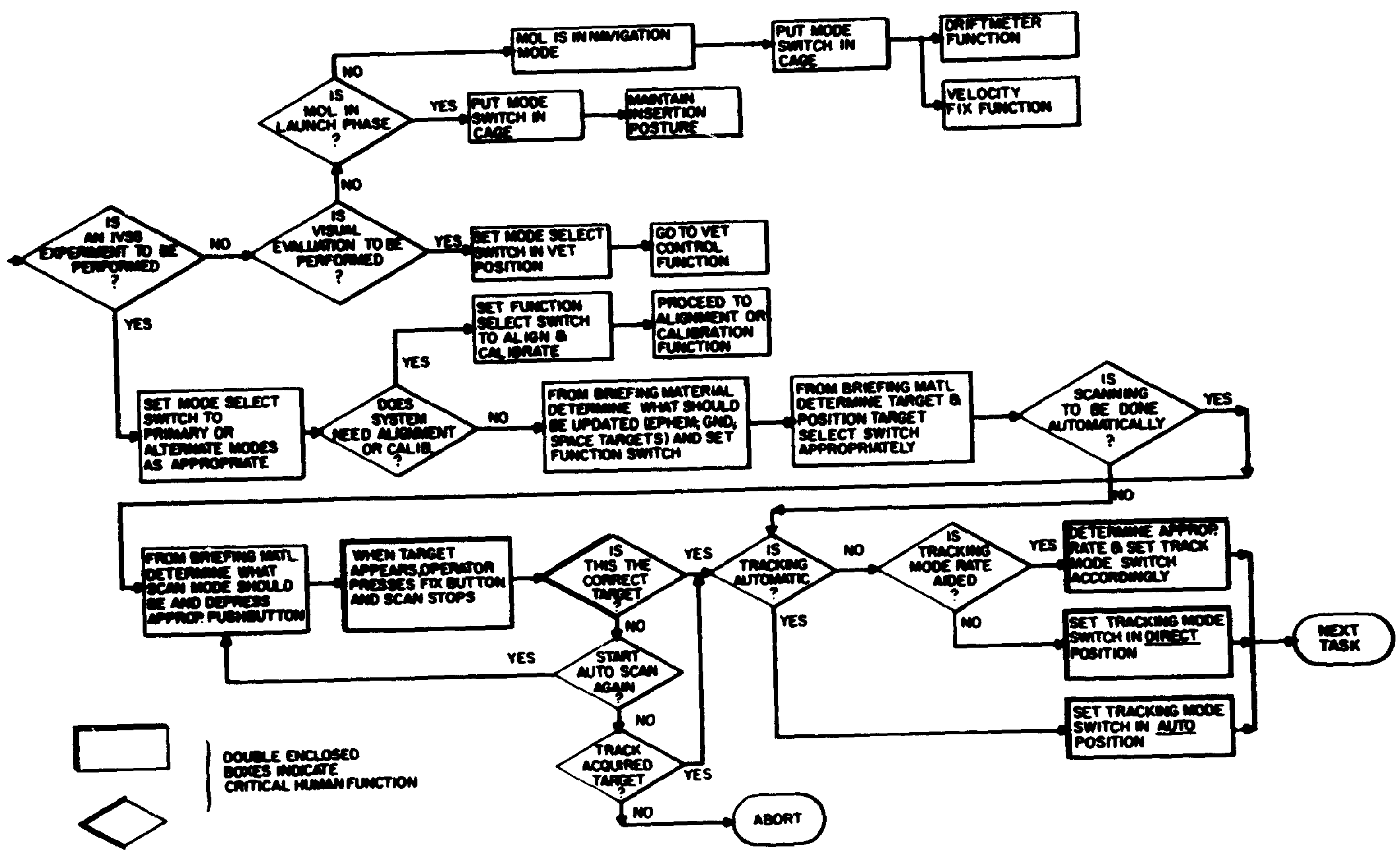


Figure 4-6. Task Flow for Mode Control Function-Station I

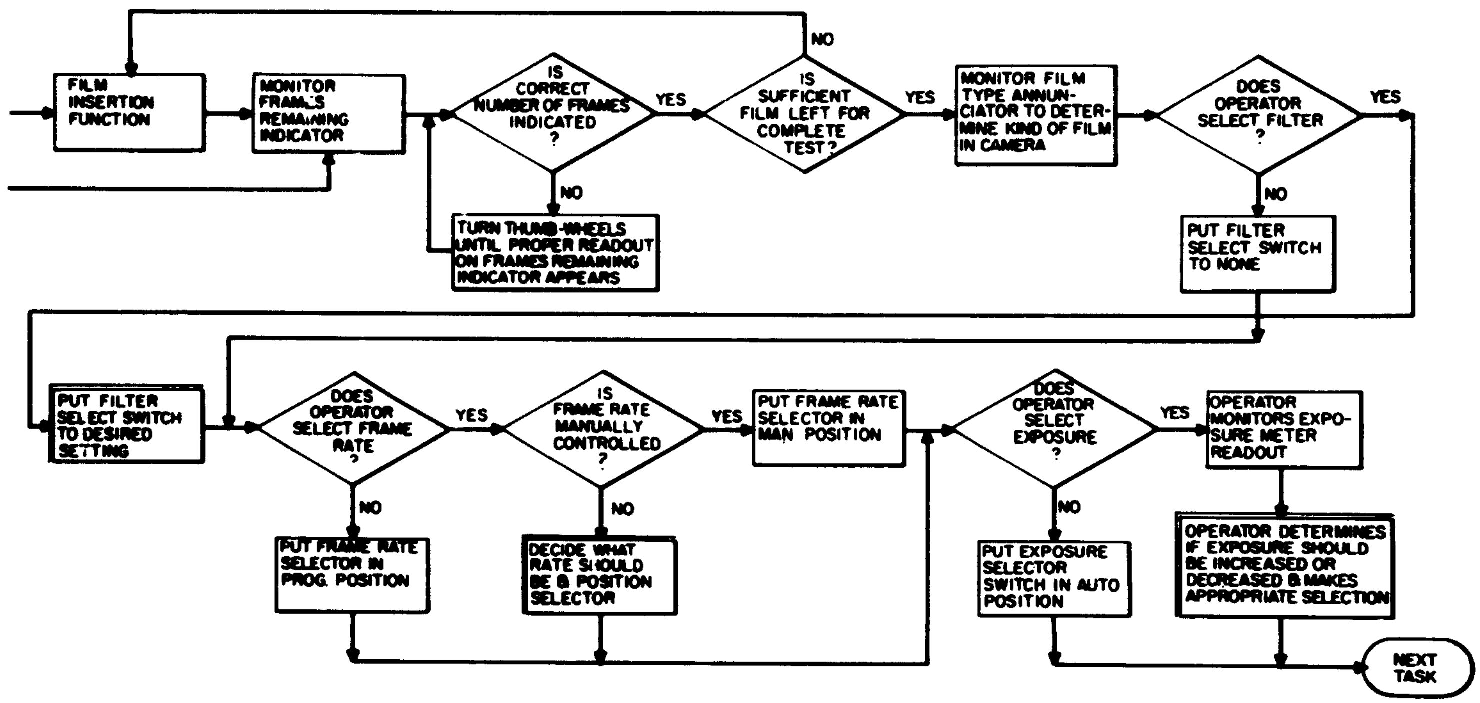


Figure 4-7. Task Flow for Camera Control Function-Station I

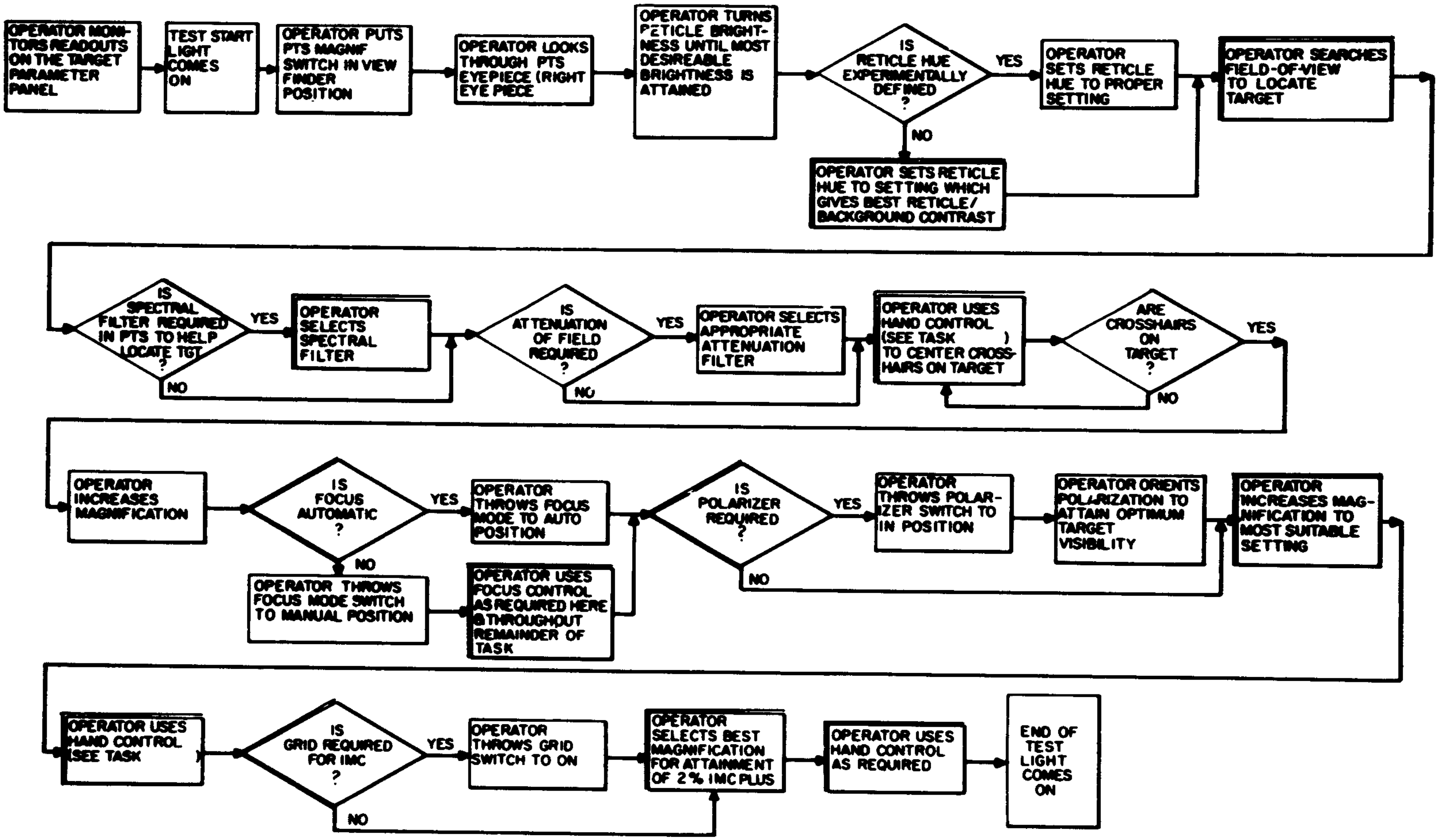


Figure 4-8. Task Flow for FTS Control Function-Station I

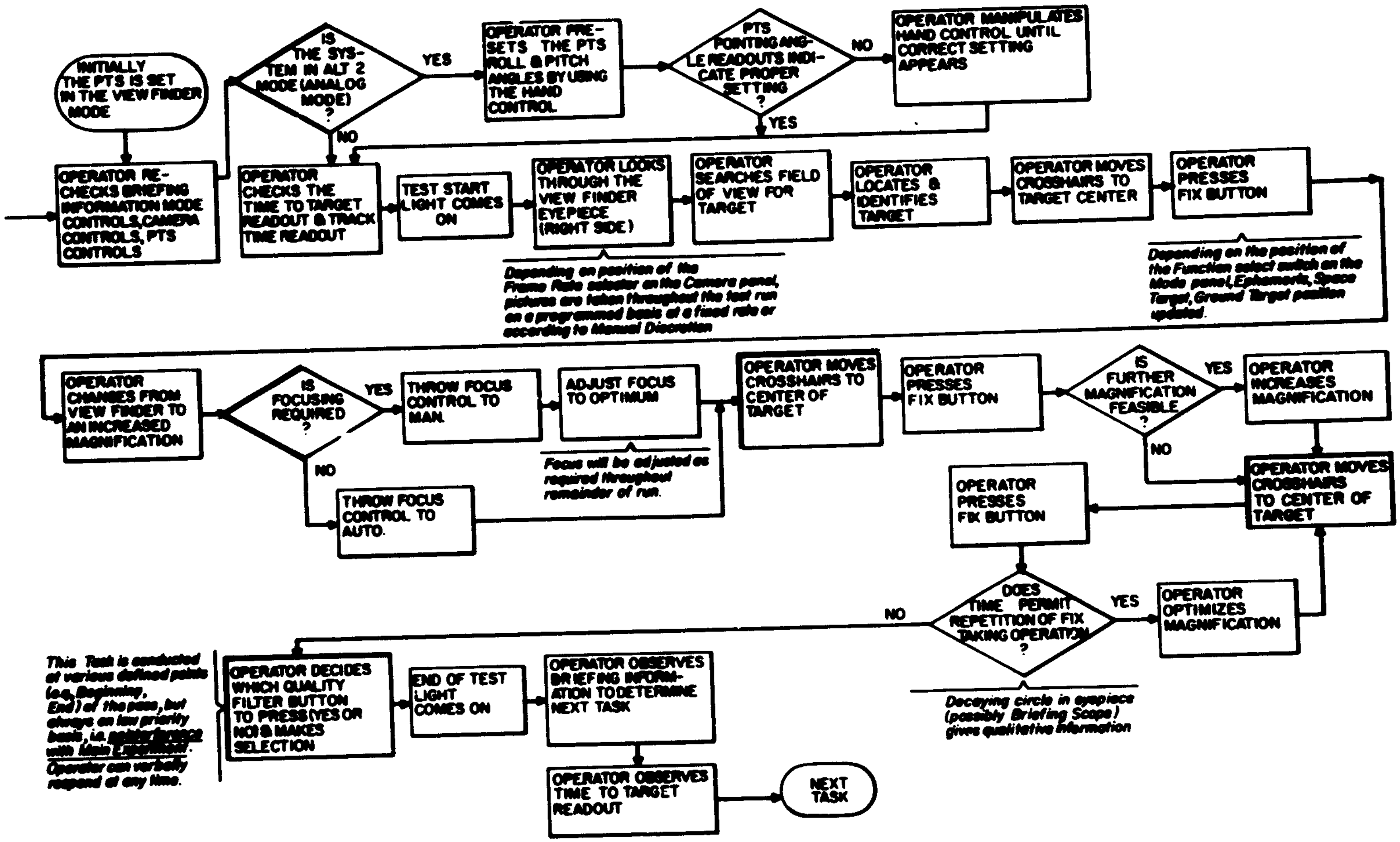


Figure 4-9. Task Flow for Tracking Function-Station I

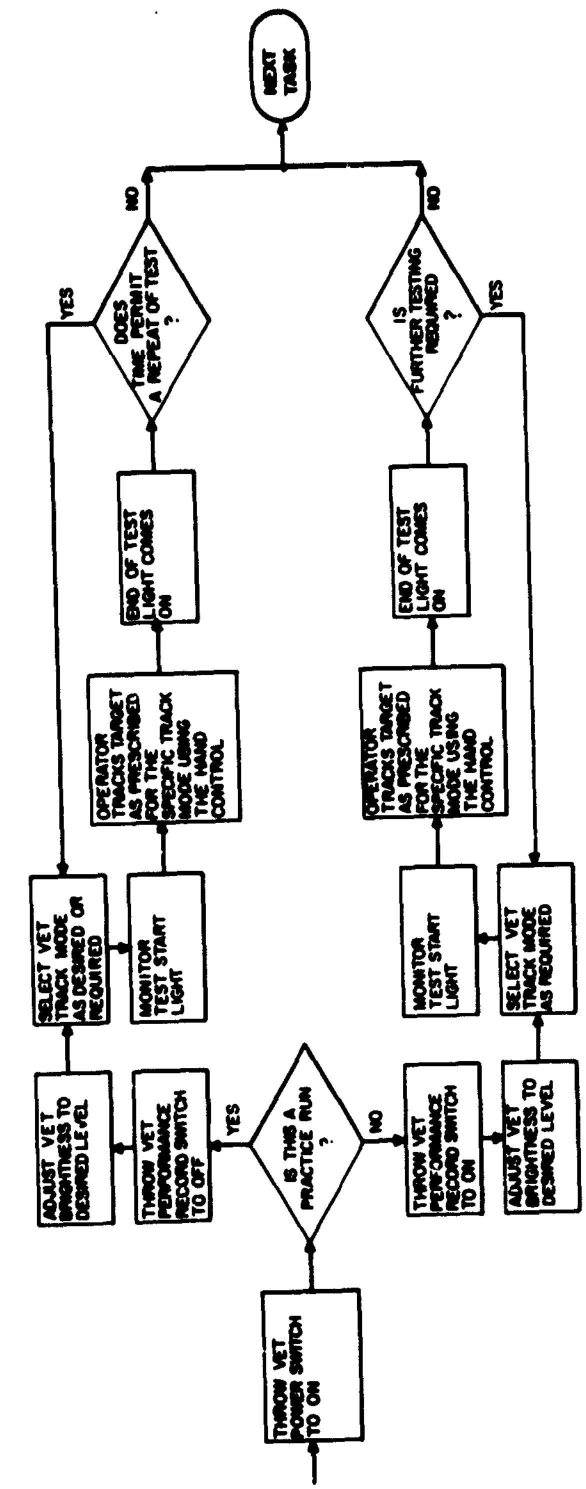


Figure 4-10. Task Flow for VET Function-Station I

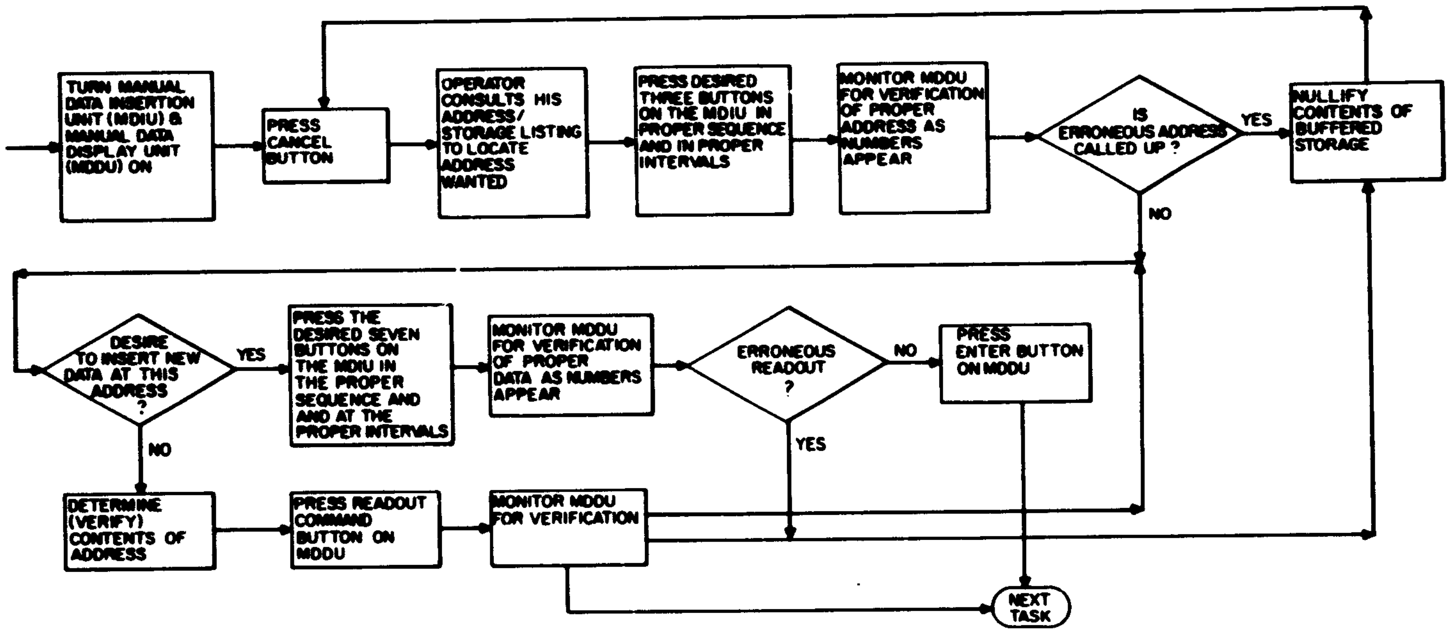


Figure 4-11. Task Flow for MDIU & MDDU

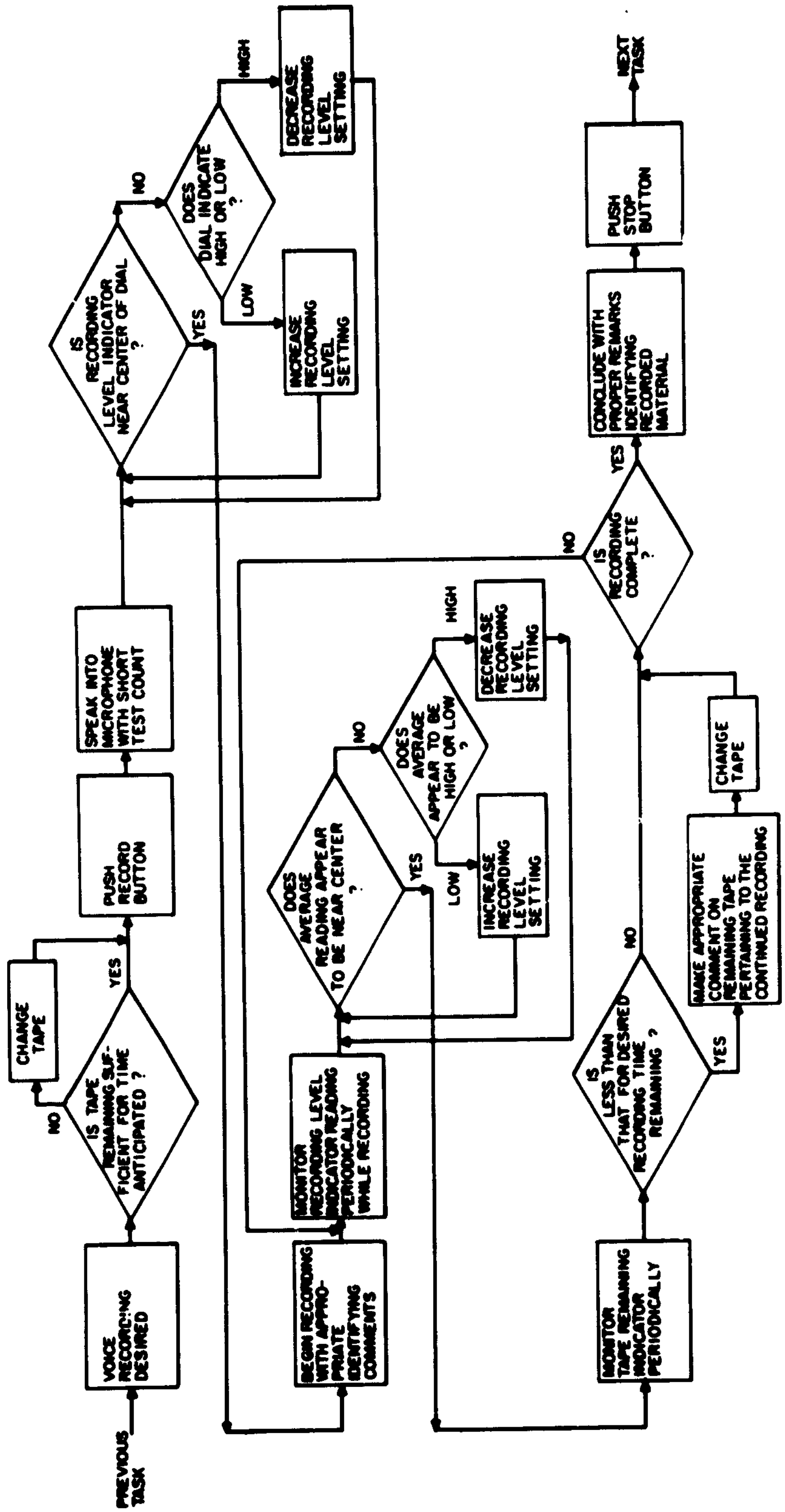


Figure 4-12. Task Flow, Voice Commentary During Experiment

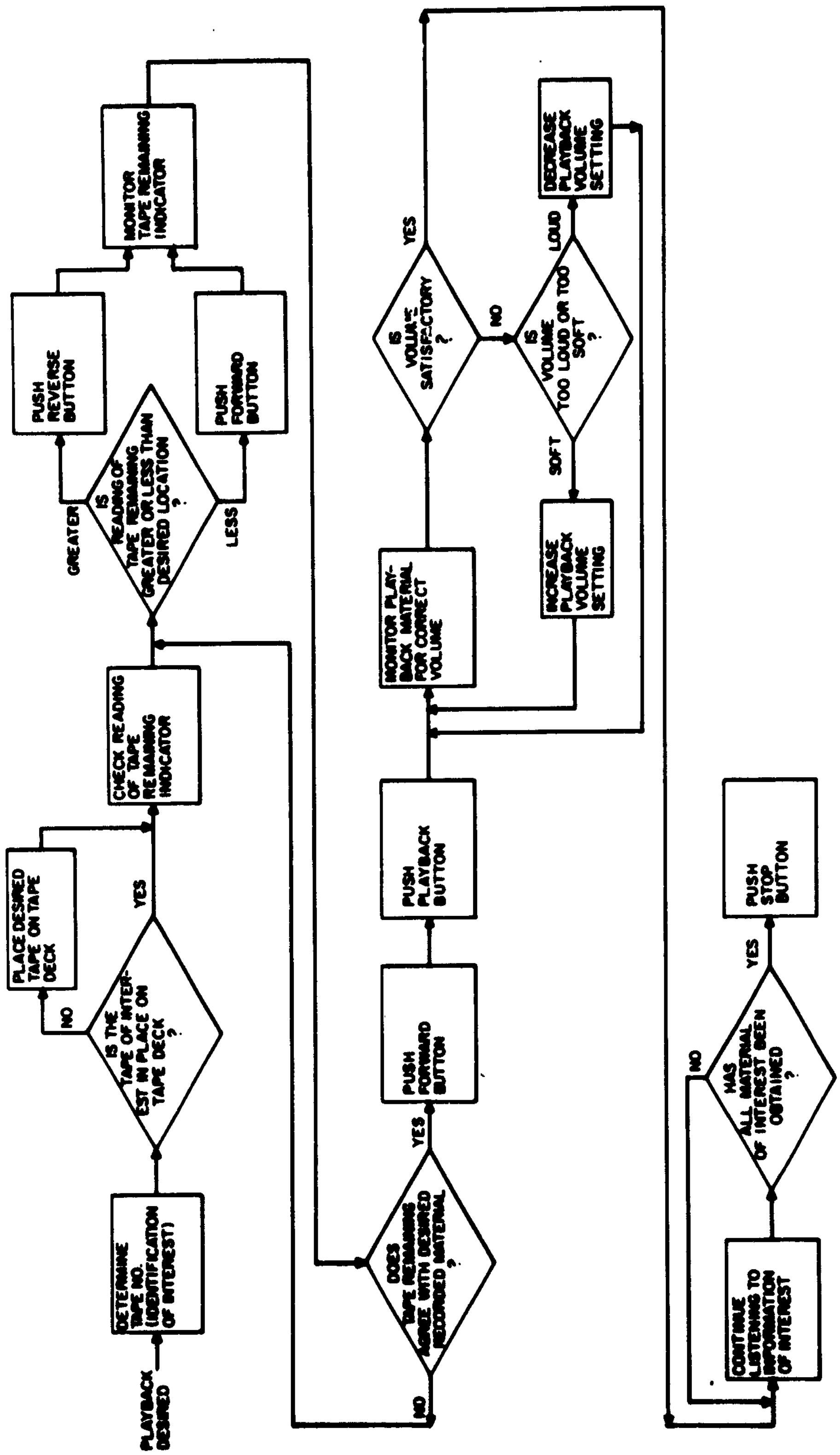


Figure 4-13. Task Flow-Recorder Playback

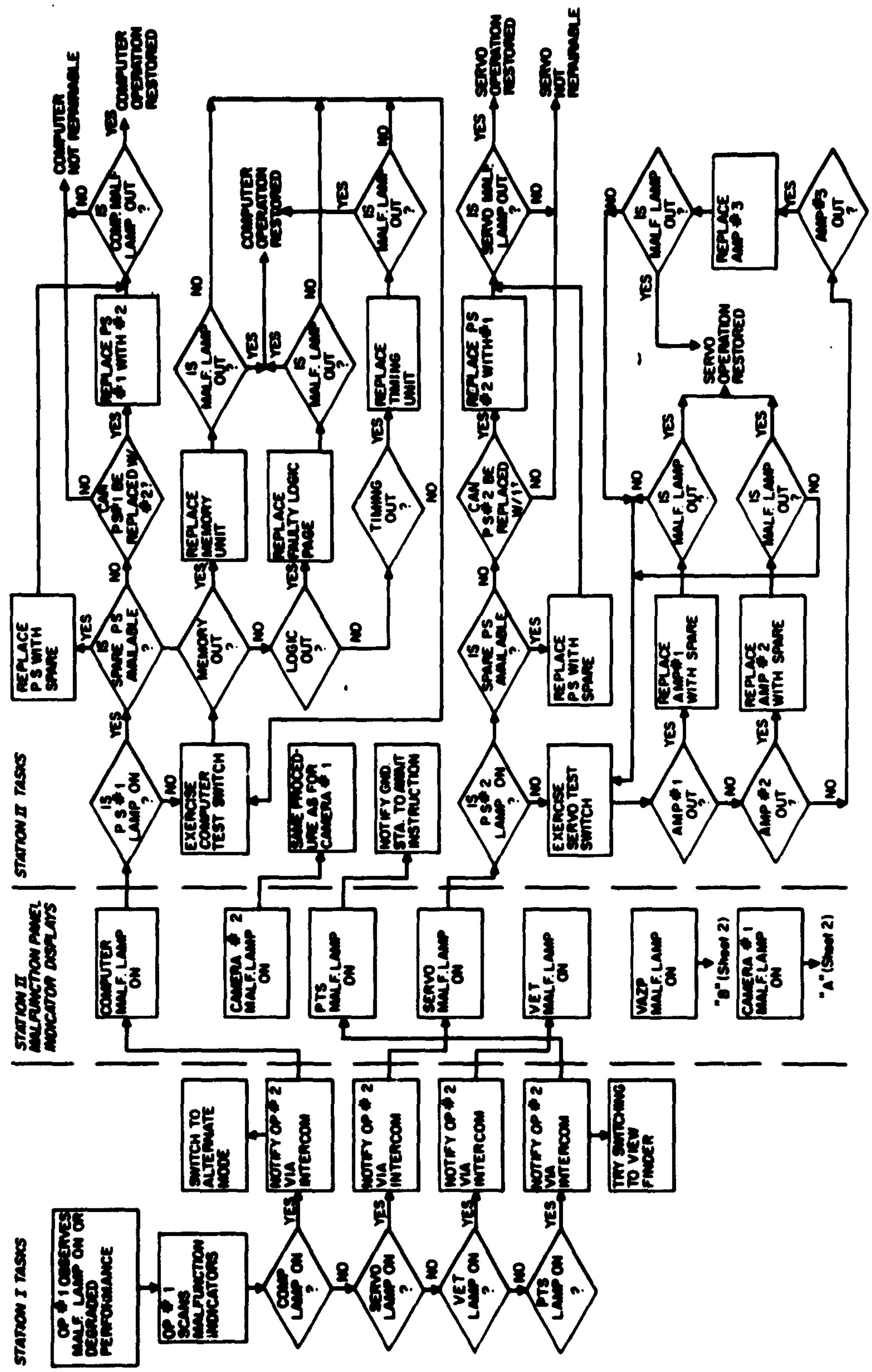


Figure 4-14. Task Flow for Malfunction (Sheet 1 of 2)

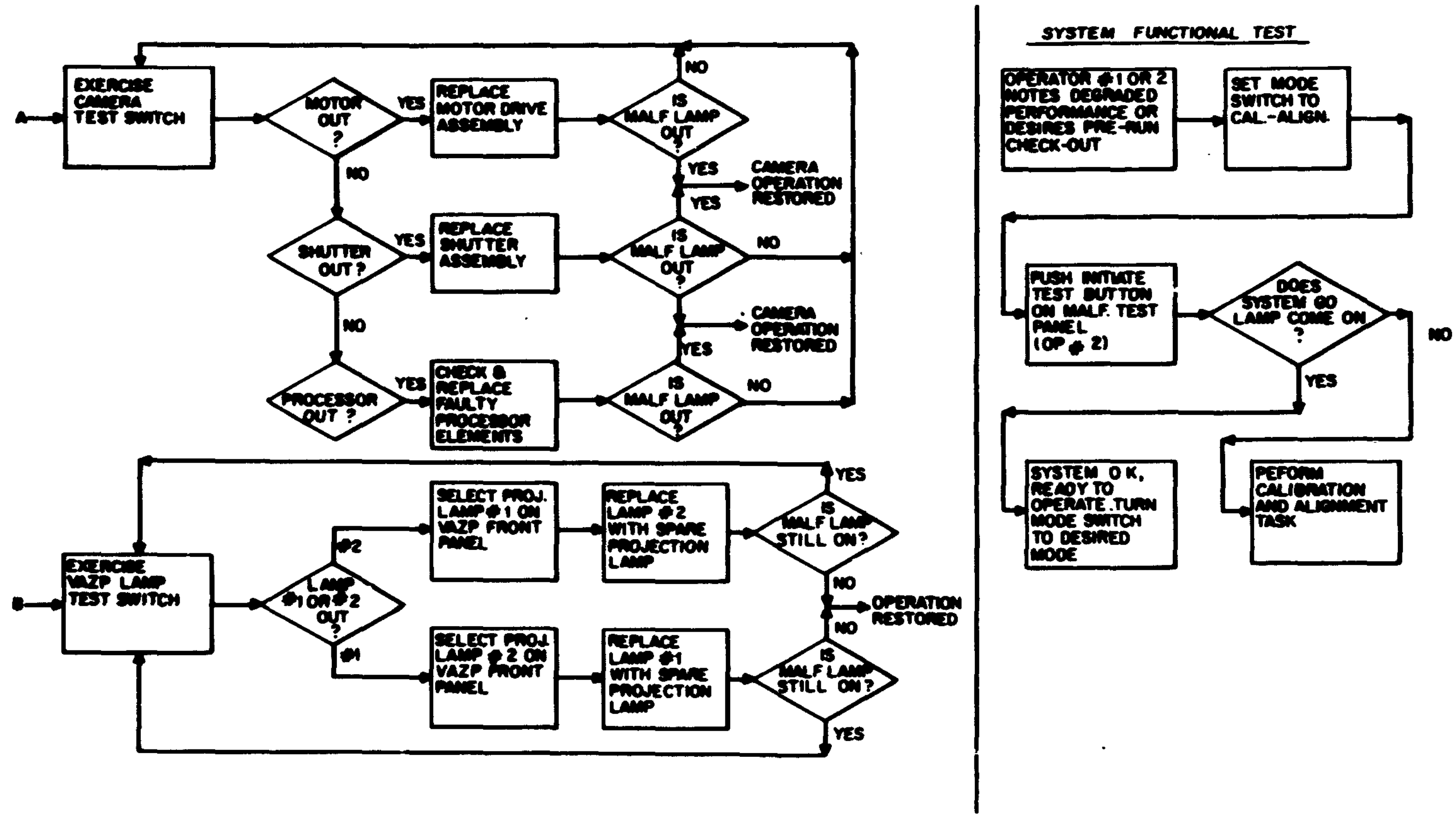


Figure 4-14. Task Flow for Malfunction (Sheet 2 of 2)

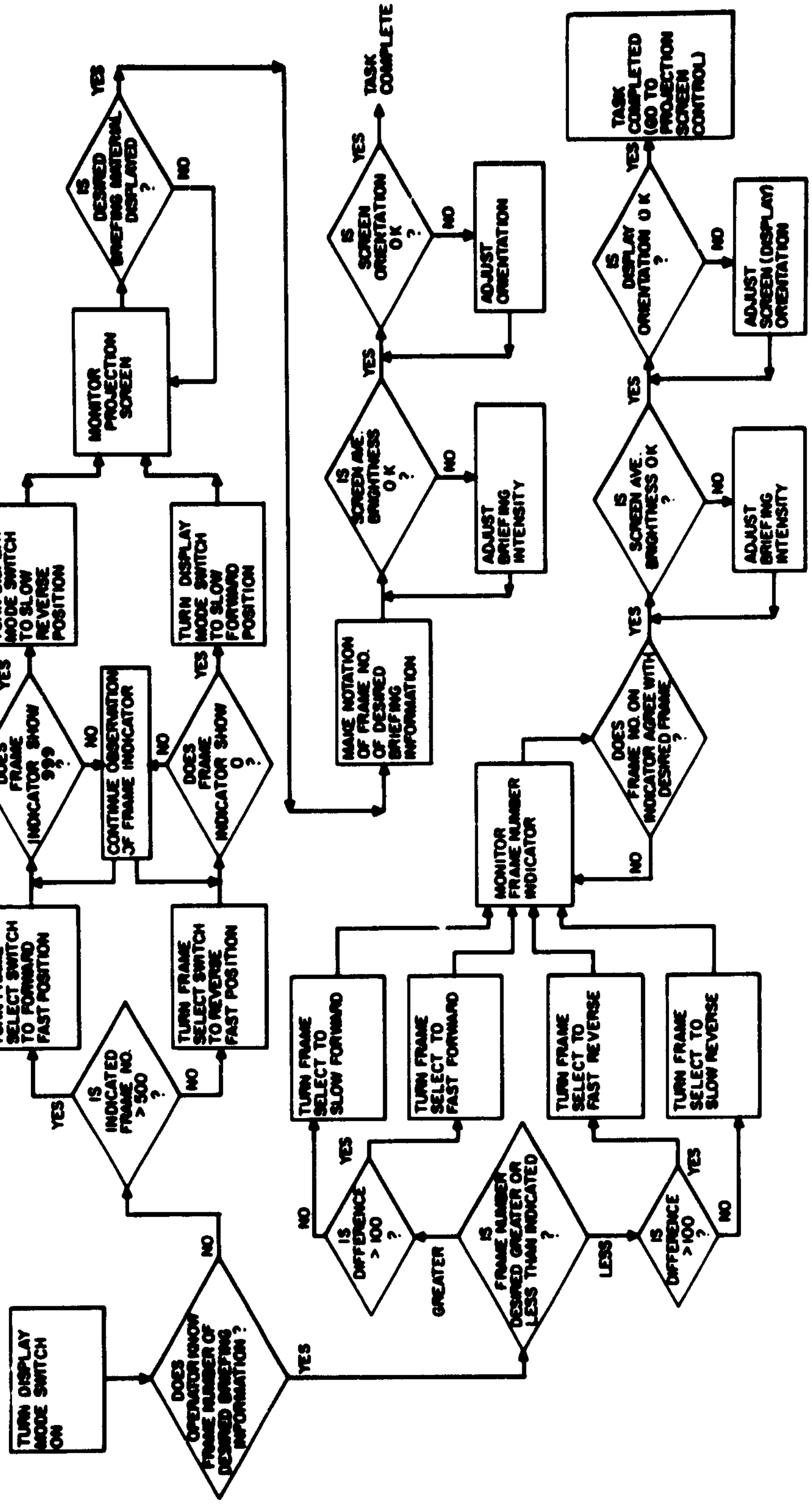


Figure 4-15. Task Flow for Photo-Data Function-Station II

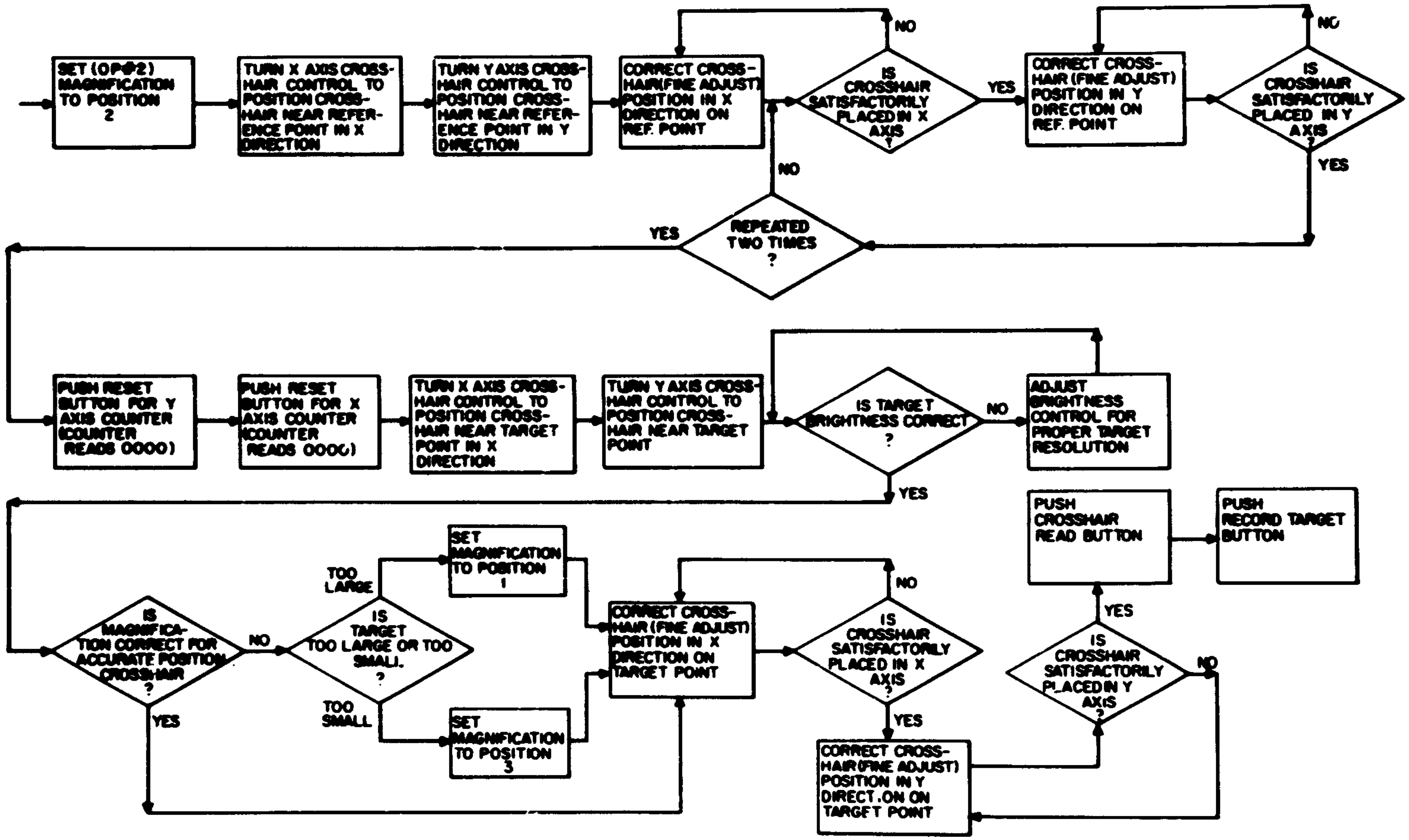


Figure 4 - 16. Task Flow for Projection Screen Operation-Station II

4.3 Time Line Analysis

One important question to be answered before continuing was, whether or not, under the extreme physical and experimental time constraints, the operator could perform the many and varied tasks without interfering with the acquisition and tracking functions of the primary experiments. It is clear, of course, a priori, that functions performed on Station II would not cause any problem since it does not have functions required on a real-time basis and secondly, it is not directly involved in any experiments performed at Station I. Figure 4-17 shows the estimated time requirements for a typical data reduction task. Basically, the function here is to place the crosshairs on at least two different points (reference point and target point) and measure the relative distance between them. Analysis of photographic content is accomplished here also. Figure 4-18 is a graph of the estimated time requirements for performance of Experiment P-1.2, Figure 4-19 is the use of the Visual Evaluation Tracker (VET). The VET test takes sufficient time so as to require that it not be performed during an experimental pass over the ZI. However, this requirement in no way interferes with the experimental design (see Section 3.0) which requires that VET testing be accomplished at least every second day at low workload periods. Of the three Time Lines, the one included for P-1.2 is the most critical because here the physical constraints are such that each target must be acquired and tracked in a matter of about 60 seconds, otherwise the target is out of view. This Time Line (Figure 4-18 includes only the case of a single target. However, for a given pass over the ZI, even though there may be five to eight targets to be looked at, this does not mean that it would take from 1-1/2 to 2 hours to perform the full experiment. If this were true, the work-load of the operator would have to be drastically reduced since it takes only on the order of 10 to 15 minutes to pass over the ZI. The saving fact is that each function is not repeated for each target and most importantly the 14-minute briefing function would not be required. Functions A (Power On) through D (Mode) would be perfromed prior to entry into the ZI. Function E (Target Parameter) through J (Quality Filtering) would be performed in varying degrees for each target. These functions (E through J) involve, in total, about 1 minute with approximately 30 seconds of that time involving tasks that require the target to be in view, i.e., starting with Function I - Tracking. This means that the other tasks might possibly be performed during the transisition period from one target to another. It appears then, that at least for these initial efforts, that the subtasks can be incorporated on a non-interference basis. This Time Line of P-1.2, (Figure 4-18 is sufficiently general to indicate that no problems are immediately evident for experiment P-3

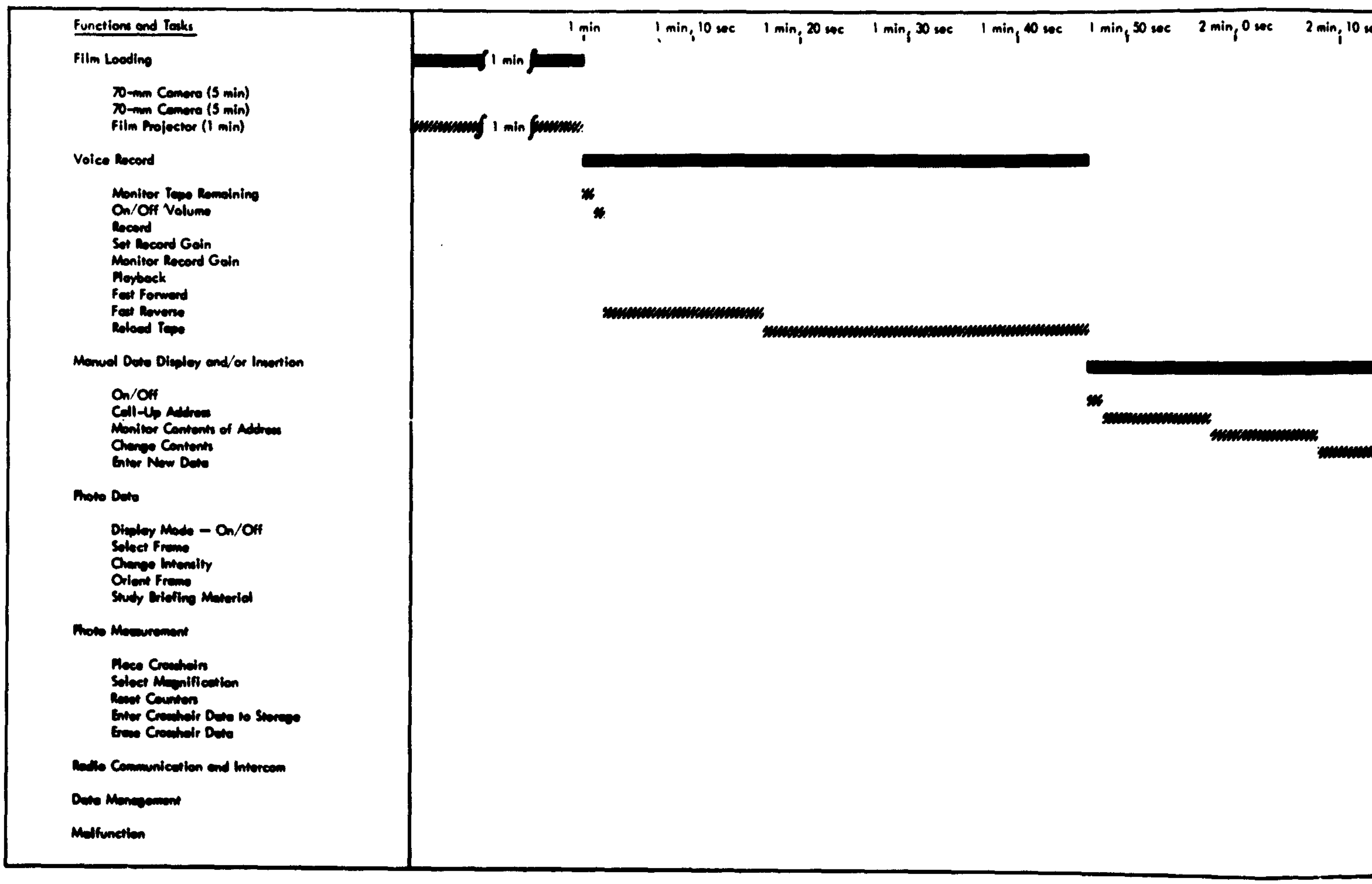
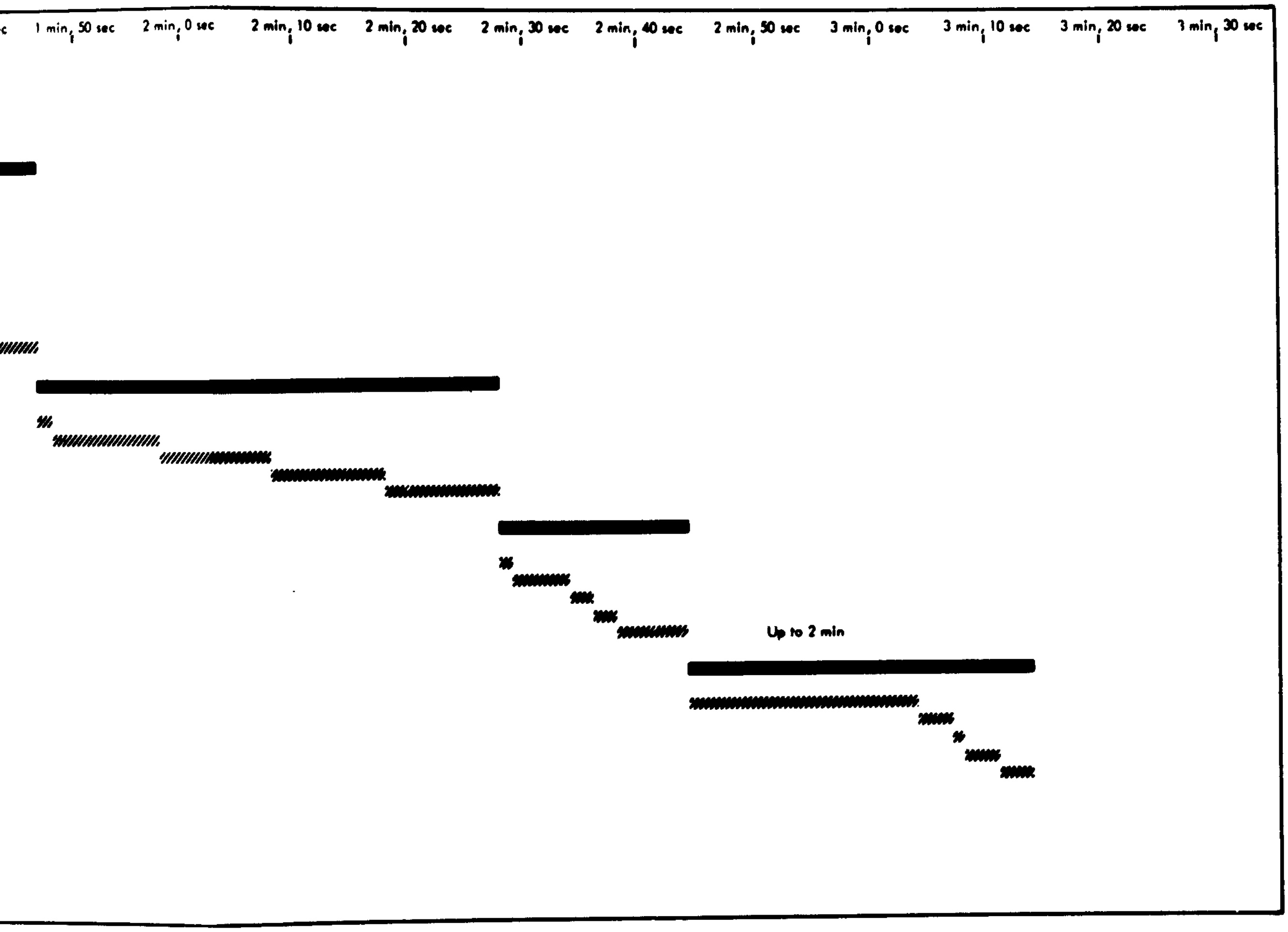


Figure 4-17. Time Line Analysis, Photo Data Measurement and Analysis


1 min, 50 sec
2 min, 0 sec
2 min, 10 sec
2 min, 20 sec
2 min, 30 sec
2 min, 40 sec
2 min, 50 sec
3 min, 0 sec
3 min, 10 sec
3 min, 20 sec
3 min, 30 sec
Up to 2 min

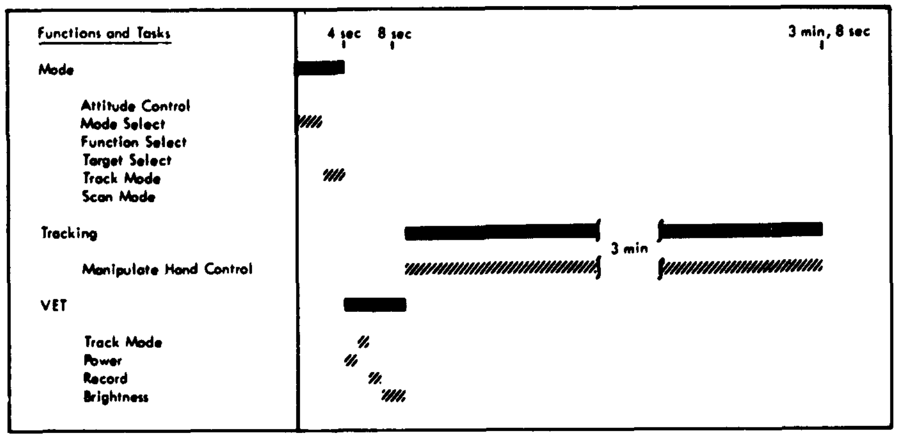


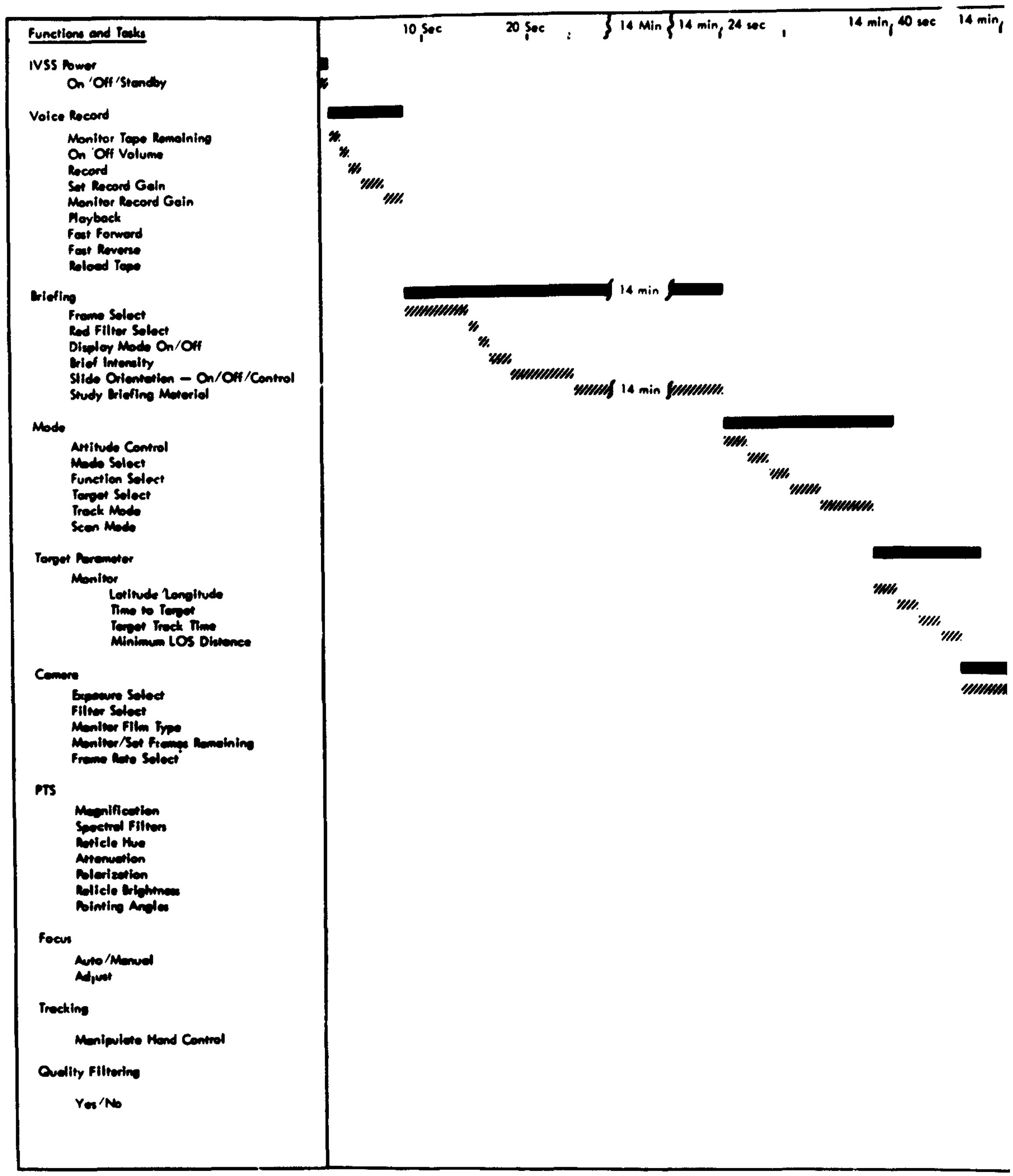
Figure 4-19. Time Line Analysis, Use of Visual Evaluation Tracker

since the experiment is very similar to P-1. Experiment P-2 is described in the Time Line of Figure 4-20. No serious time constraints are seen for typical encounters.

4.4 Training Considerations and Requirements

The skill requirements imposed upon the crew have been identified and are described in detail in Section 3.0 of this volume. These skill requirements have been translated into crew training requirements. It is highly desirable that the crew participate in the primary experiments at a combined level, that of an experimenter as well as a subject. The nature of the experiments, whose basic objectives are the assessment of human contribution, require human participation and involvement not oridnarily expected of flight crew personnel. Therefore, close attention must be paid to establishing training and selection standards as definition of the IVSS proceeds. Participation of the crew members during development and flight testing is essential to ensure an adequate combination of knowledge, technical skills, procedural skills and experience, and ego-involvement essential for experiment success.

The duration of training and phasing of the training periods have yet to be established, and will be addressed in detail during Phase I. However, in the data forms for each experiment, the basic training requirements have been identified for each experiment, which will serve as bases for training standards and training plans. Use of contractor facilities, simulators, and flight test hardware will be established and coordinated with deliveries of hardware and USAF space flight crew training programs.


Functions and Tasks
10 Sec
20 Sec
14 Min
14 min, 24 sec
14 min, 40 sec
14 min,
IVSS Power
On/Off/Standby
Voice Record
Monitor Tape Remaining
On/Off Volume
Record
Set Record Gain
Monitor Record Gain
Playback
Fast Forward
Fast Reverse
Reload Tape
Briefing
14 min
Frame Select
Red Filter Select
Display Mode On/Off
Brief Intensity
Slide Orientation — On/Off/Control
14 min
Study Briefing Material
Mode
Attitude Control
Mode Select
Function Select
Target Select
Track Mode
Scan Mode
Target Parameter
Monitor
Latitude/Longitude
Time to Target
Target Track Time
Minimum LOS Distance
Camera
Exposure Select
Filter Select
Monitor Film Type
Monitor/Set Frames Remaining
Frame Rate Select
PTS
Magnification
Spectral Filters
Reticle Hue
Attenuation
Polarization
Reticle Brightness
Pointing Angles
Focus
Auto/Manual
Adjust
Tracking
Manipulate Hand Control
Quality Filtering
Yes/No

1

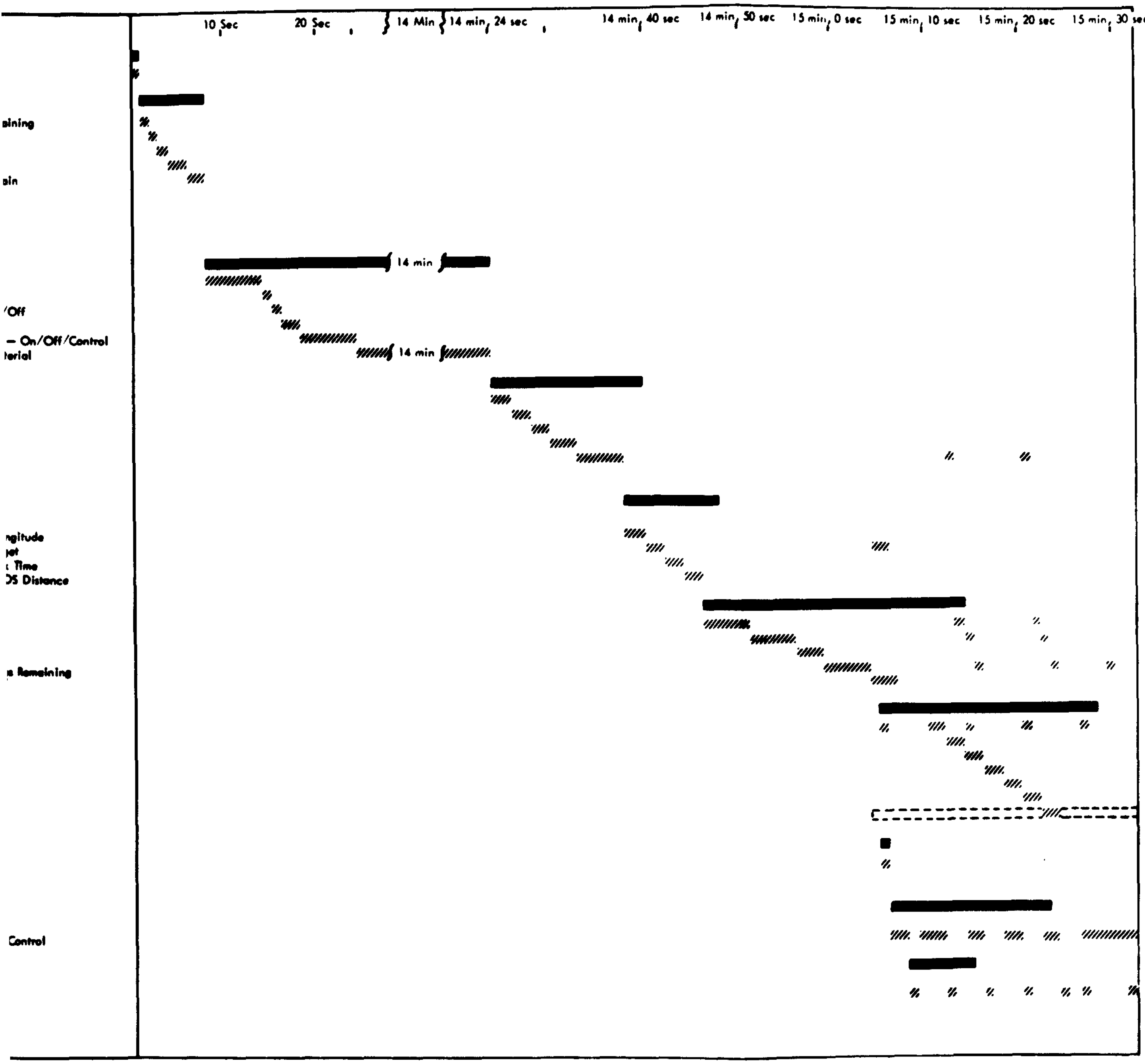


Figure 4-18. Time Line Analysis, Acquisition and Tracking of Ground Targets

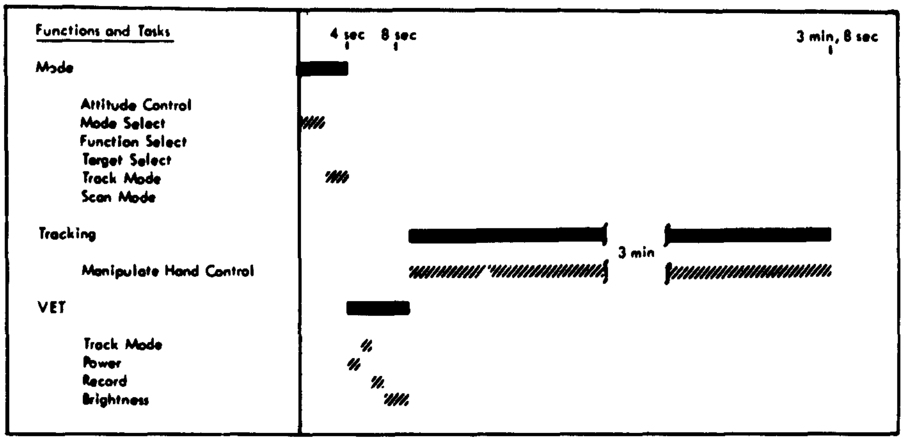


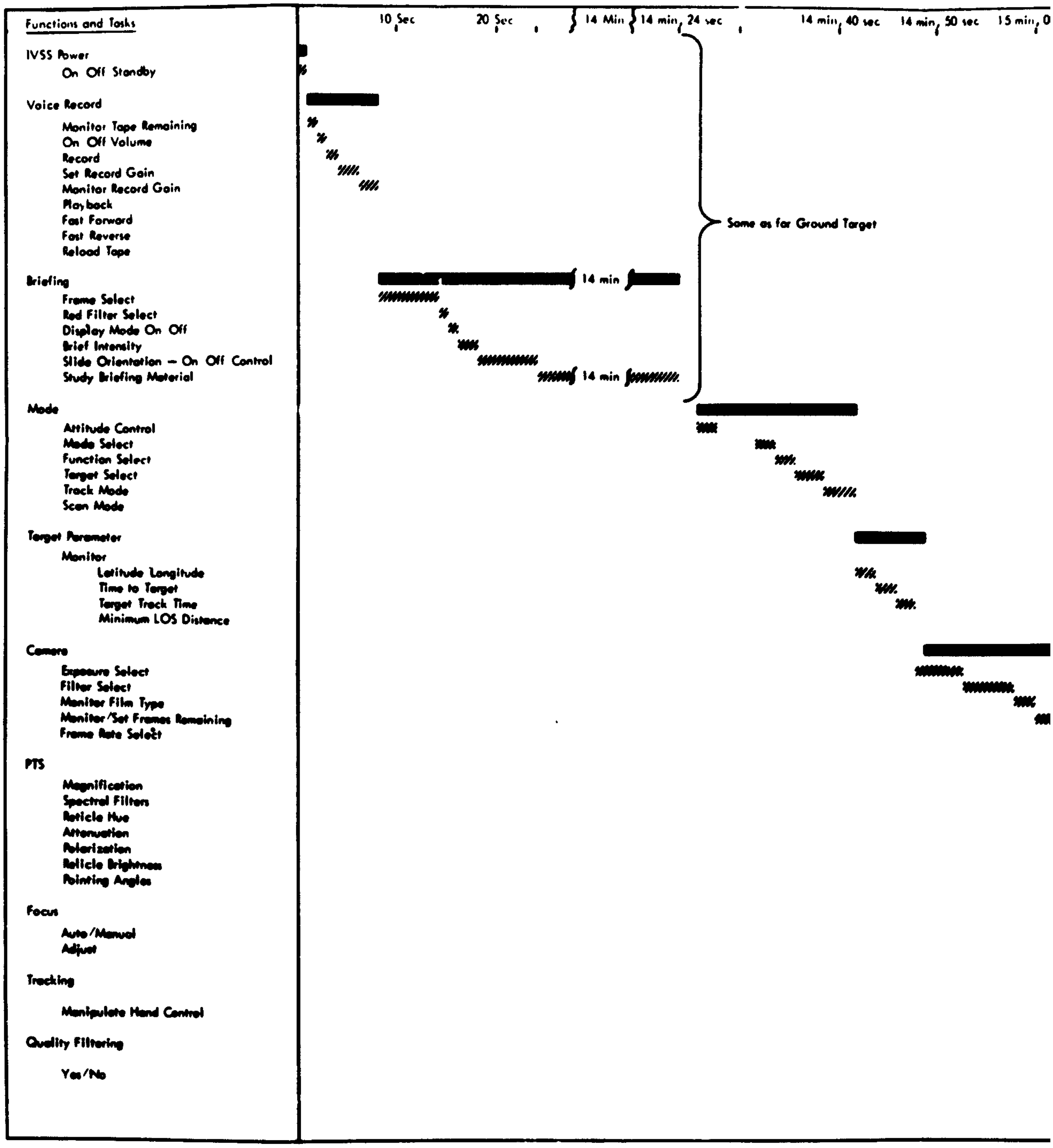
Figure 4-19. Time Line Analysis, Use of Visual Evaluation Tracker

since the experiment is very similar to P-1. Experiment P-2 is described in the Time Line of Figure 4-20. No serious time constraints are seen for typical encounters.

4.4 Training Considerations and Requirements

The skill requirements imposed upon the crew have been identified and are described in detail in Section 3.0 of this volume. These skill requirements have been translated into crew training requirements. It is highly desirable that the crew participate in the primary experiments at a combined level, that of an experimenter as well as a subject. The nature of the experiments, whose basic objectives are the assessment of human contribution, require human participation and involvement not oridnarily expected of flight crew personnel. Therefore, close attention must be paid to establishing training and selection standards as definition of the IVSS proceeds. Participation of the crew members during development and flight testing is essential to ensure an adequate combination of knowledge, technical skills, procedural skills and experience, and ego-involvement essential for experiment success.

The duration of training and phasing of the training periods have yet to be established, and will be addressed in detail during Phase I. However, in the data forms for each experiment, the basic training requirements have been identified for each experiment, which will serve as bases for training standards and training plans. Use of contractor facilities, simulators, and flight test hardware will be established and coordinated with deliveries of hardware and USAF space flight crew training programs.


Functions and Tasks
IVSS Power
On Off Standby
Voice Record
Monitor Tape Remaining
On Off Volume
Record
Set Record Gain
Monitor Record Gain
Playback
Fast Forward
Fast Reverse
Reload Tape
Briefing
Frame Select
Red Filter Select
Display Mode On Off
Brief Intensity
Slide Orientation – On Off Control
Study Briefing Material
Mode
Attitude Control
Mode Select
Function Select
Target Select
Track Mode
Scan Mode
Target Parameter
Monitor
Latitude Longitude
Time to Target
Target Track Time
Minimum LOS Distance
Camera
Exposure Select
Filter Select
Monitor Film Type
Monitor/Set Frames Remaining
Frame Rate Select
PTS
Magnification
Spectral Filters
Reticle Hue
Attenuation
Polarization
Reticle Brightness
Pointing Angles
Focus
Auto/Manual
Adjust
Tracking
Manipulate Hand Control
Quality Filtering
Yes/No
10 Sec
20 Sec
14 Min
14 min, 24 sec
14 min, 40 sec
14 min, 50 sec
14 min
14 min
Same as for Ground Target

1

Figure 4

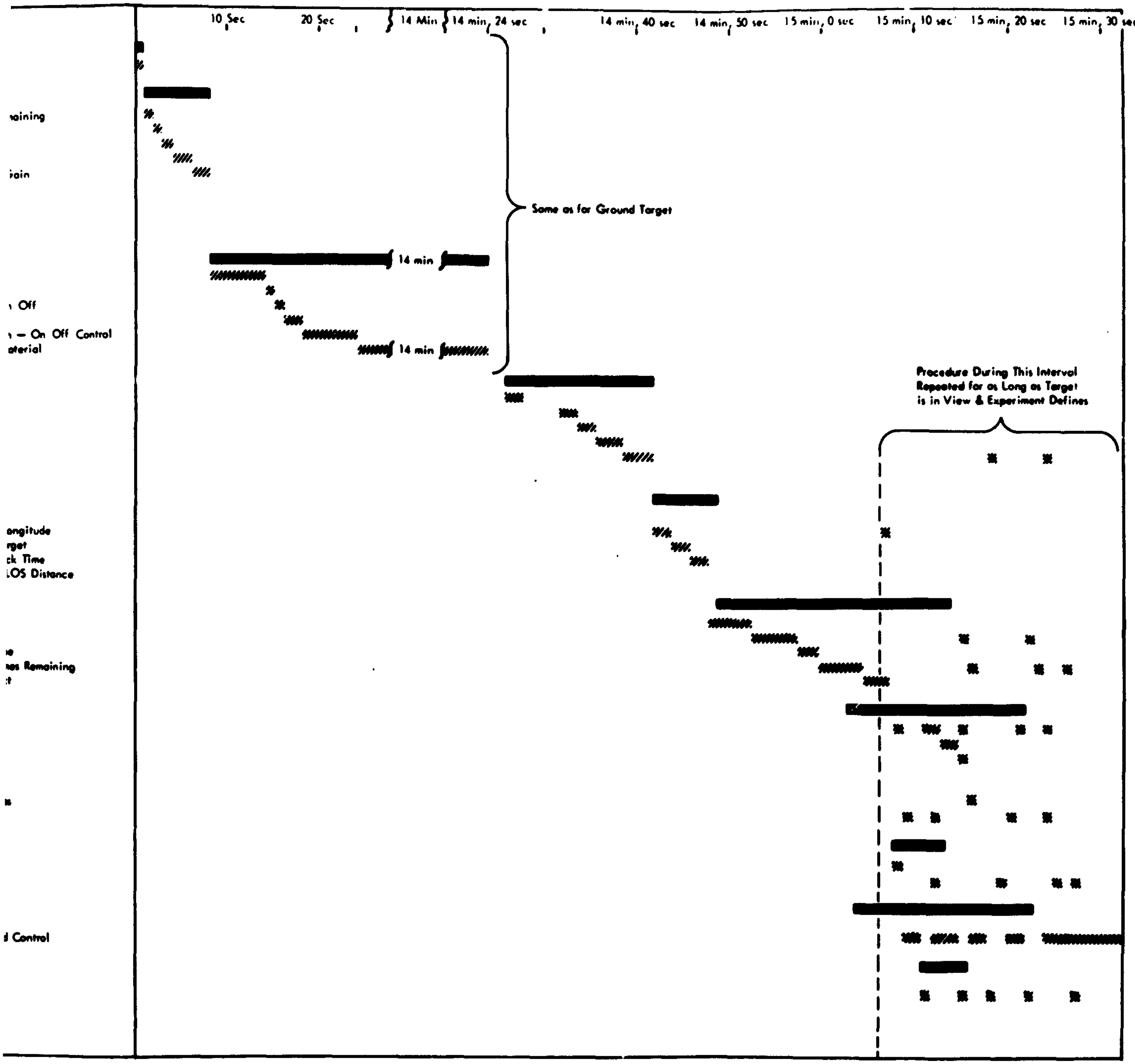


Figure 4-20. Time Line Analysis, Acquisition and Tracking of Typical Co-Planer Target

4.5 Maintainability Requirements

The daily scheduled maintenance time is estimated to be 15 minutes. This will consist mainly of routine checkout, alignment, and calibration, when required. One of the areas to be jointly investigated by human factors and maintainability engineering during Phase I will be that of providing a high confidence check on system status that would circumvent the need for routine alignment and calibration at the beginning of each working period. Attempt will be made to define an overall system functional test incorporating quantitative accuracy tests to provide confidence level sufficient for elimination for calibration and alignment. That is, if the system will pass the overall end-to-end functional test, it can be assumed that calibration and alignment are within acceptable limits. Considerable effort will be extended toward feasibility and definition of such a test that will be exhaustive in nature, yet rapidly executed and simply inplemented.

The anticipated Mean Time To Repair (MTTR) is 1.3 hours. The average daily unscheduled maintenance time (UMT), however, is only 0.01 hours because of the relatively high ratio of MTBF (Mean Time Between Failures) to mission length. (For more detailed information consult the Reliability and Maintainability portion of this report, Volume III, Section 6.6.)

5.0 Human Engineering Considerations

5.1 Establishing Control and Display Requirements

During the preliminary design stages of the IVSS, the approach to definition of the crew interface has been to represent all important operational and experimental functions on the console. Therefore, as design efforts continue, the interface will undergo considerable change. The IVSS Console Layout is presented in Figure 5-1. Once the form factors become more rigidly defined, the positioning of the various sub-panels and controls will change. It is expected that the PTS and camera controls will most likely change type and locations as a function of form factor, accessability, maintainability, and considerations of optimizing the operability of the system. For example, when the subsystem is further developed, it is highly probable that the controls for the two cameras may be located on the cameras themselves. An example of a potential control relocation is the PTS magnification. In the next phase, the feasibility of making this a foot control will be examined along with manual back-up considerations. Overall simplification of the individual tasks is an area requiring study once equipment requirements begin to become firm. The manual exposure select task has already been reduced to two choices; the choice being simple multiples of the automatic exposure. Areas needing similar task reduction include the manual camera frame rate selection and also filter selection for both cameras and the PTS.

5.2 Console Layout

The basic console design evolved from the functional and task analyses previously discussed. It is seen (see Figure 5-1, IVSS Console Layout) that the console consists of two independent work stations. Station I permits performance of the three primary IVSS experiments, while Station II is provided for data management and analysis. There is a center console area which is shared between the two stations primarily for data management and communications. Each station is divided into functional areas with each function panel corresponding to a function defined in Section 4.0. The panel consists of the controls used to fulfill the functions defined in the Task Analysis Flow Charts (see Figures 4-1 through 4-16.)

This approach not only gave a convenient logical grouping of controls and displays, it provided a great flexibility and capability for incorporating changes. Since the system analysis and design was in a continuous state of flux, this capability was extremely important in updating the console and keeping it current.

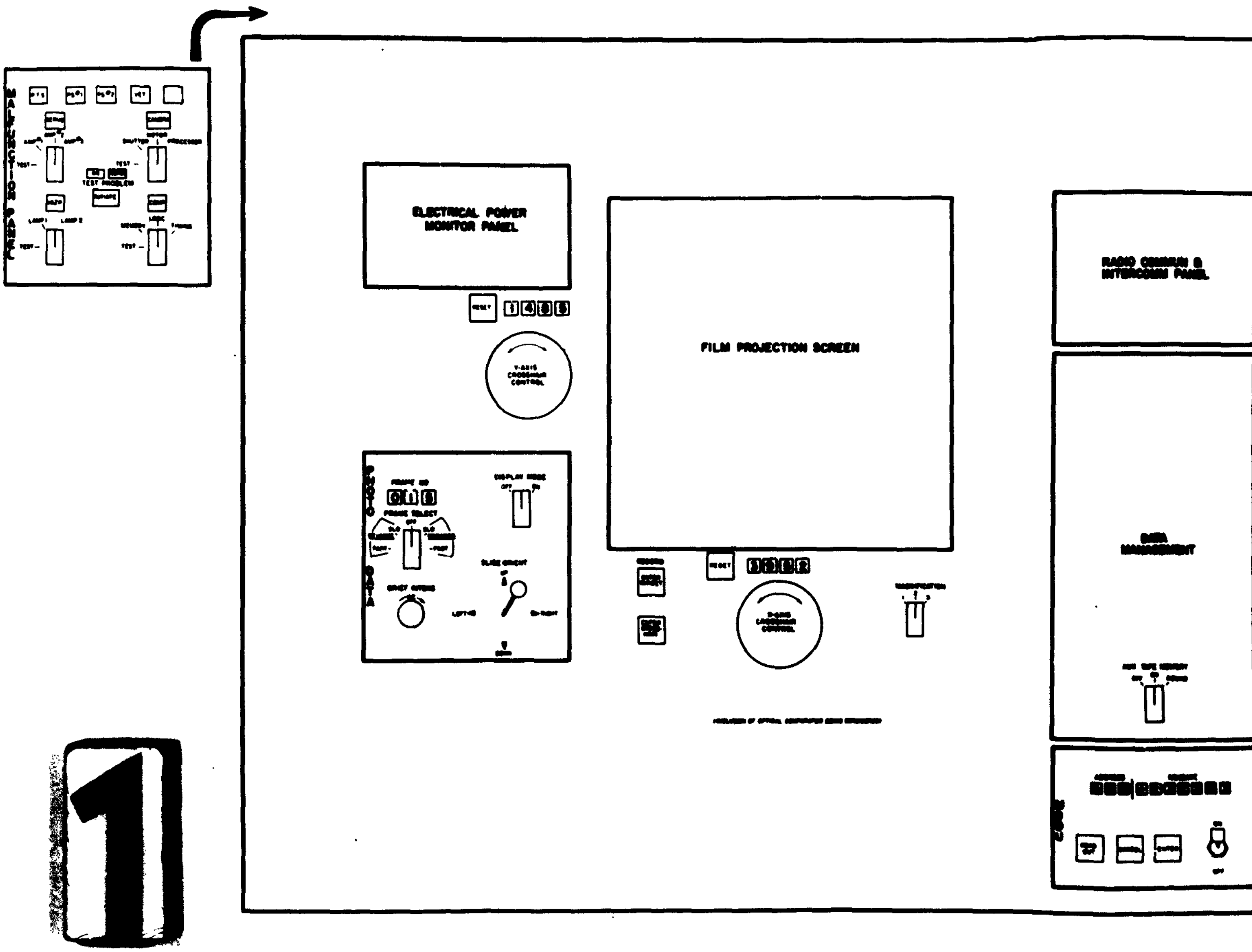
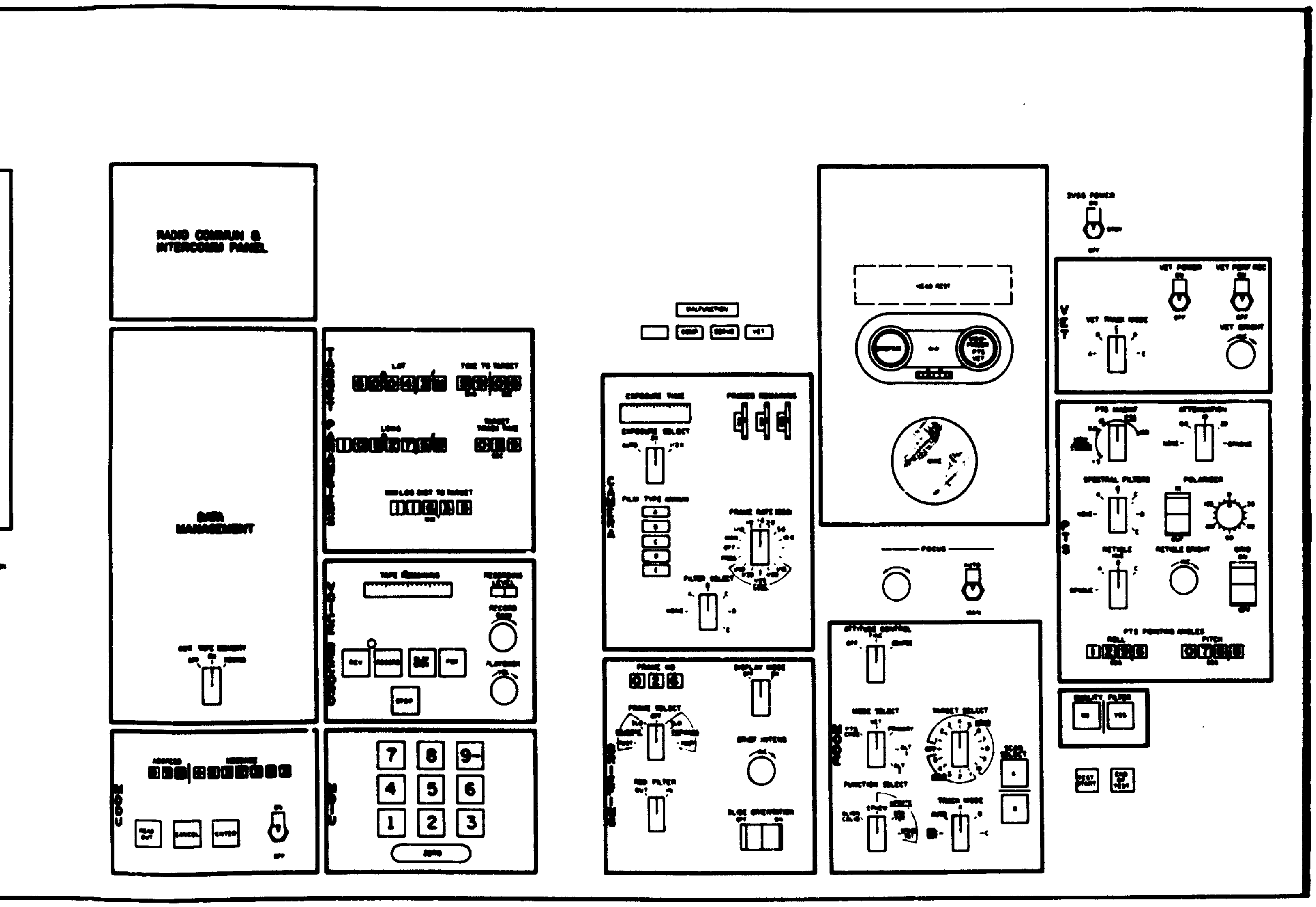


Figure 5-1. IVSS Operator Subsystem Interface


RADIO COMMUN &
INTERCOMM PANEL
DATA
MANAGEMENT
FOCUS
7 8 9
4 5 6
1 2 3

2

The procedure followed in laying out Station I was to group those controls that are expected to be used while the operator is looking through an eyepiece, in the high priority areas close to the eyepieces. Design was also such as to reduce the need to move the head away from the eyepiece at any time during the acquisition and tracking, and for those cases where it would be necessary to move the head, such movement would be small.

In general, it is felt that it is somewhat early to define knobs, buttons, or readouts in extreme detail and to rigidly hold to these controls and displays. However, some judgements were made as to what they might be and are included in Table 5-1 IVSS Controls and Displays List. This functional listing served as a preliminary specification of how the operator interfaces with the subsystem. The control and display list also permitted incorporation of switches in the system math flow, described in Volume III.

The Human Engineering contribution to the IVSS development will enter a crucial period during Phase I. In the next phases of the effort considerable attention will have to be given to such problems as toxicity due to on-board film development, detailed design of band controls, etc. With hardware becoming better defined, a closer look at PTS/Camera/Reference Axis Alignment, as well as the previously mentioned task simplification, will be made. Anthropometric problems such as chair design, head rests, and head restraints will also have to be resolved. Another critical area will be the interior lighting problem. The possibility of having to shield the data reduction section of the console from the PTS section may be a requirement since the illumination requirements for each station are somewhat different. Further, the PTS operator has a somewhat unique eye adaptation problem. Since he will be passing from high to low light levels fairly rapidly, he'll be required to detect space targets, ground targets, sea targets, and even sight on the dark side of the orbit on lighted complexes. The internal lighting must be such that the operator can accommodate this wide range of illumination that he will encounter, while permitting a second operator to occupy station II if required.

The desirability of measuring human team contribution with the IVSS has been established. Provided systems design, functional capabilities, and the console reflect two-man requirements, advantages will accrue in several key operational areas. Several immediate operational advantages will accrue in several key operational areas. Several immediate

advantages are: (1) critique and subjective analysis of subject operator performance and system behavior by a second operator using a second eyepiece, who is not "task-loaded", (2) a probable increase in human efficiency and reliability in the conduct of the experiment protocol by use of check-lists, division of labor, etc., and (3) a significant increase in operational capability for handling "targets of opportunity", provided two-man requirements are factored into systems design.

When considering the entire experimental package, two-man operation appears very likely. The incorporation of a two-man operational capability into the IVSS, permitting two operators to view simultaneously as well as cooperation and hand-off of tasks, is recommended as an area of study during Phase I. The limits of man's capabilities may be significantly greater as a team, provided appropriate system capability, than alone, necessitating measurement of this capability during laboratory deployments subsequent to establishing fundamental human capabilities.

5.2.1 The Hand Controller

Electronic and physical design characteristics of the hand controller are included in Volume III. The controller has undergone several major revisions during the course of the elemental simulation studies, as tracking and system feedback requirements were defined, and subject performance and commentary was assessed. Considerations of less mass, greater tactual feedback, and finer resolution and linearity have been incorporated in the controllers that were used for the final phase of elemental simulation.

The current design, rate plus proportional control, reflects the requirement for precision tracking of terrestrial and space targets over a variety of dynamic constraints. Phase I design studies will emphasize electronic design, mass and dynamic characteristics, form factors, and interface of the hand controller with the IVSS.

Table 5-1
IVSS CONTROLS AND DISPLAYS

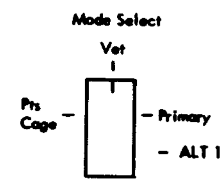
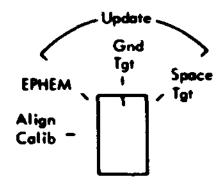
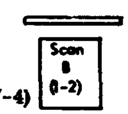
Panel: Control/Display	Position	Function	Type	Remarks
<u>IVSS MODE PANEL:</u>				
(SW-1) MODE SELECT		Operator Control of Major IVSS Modes	(Rotary Selector) (4 position)  	
(Pos. 1) PTS CAGE	PTS Cage	Scanning elements of PTS are caged.		
(Pos. 2) VET	Visual Eval. Tracker	IVSS in Visual evaluation tracking mode.		
(Pos. 3) PRIMARY	Primary Mode (Digital)	IVSS in Primary Mode		
(Pos. 4) ALTERNATE 1	Alternate Mode (Digital)	IVSS Alternate Mode 1		
(Pos. 5) ALTERNATE 2	(Alternate Mode (Analog)	Alternate Mode 2		
(SW-2) FUNCTION SELECT		Operator Selection of Track or Fix Function Alignment-Calibration Function	(Rotary Selector) FUNCTION SELECT  	
(Pos. 1) Align/Calib.	Align-Calibrate			
(Pos. 2) Ephemeris	Ephemeris Update	Ephemeris updated if Fix switch depressed		
(Pos. 3) GND TGT.	Gnd. Tgt. Update	Gnd. Tgt. coordinates updated if Fix switch depressed		
(Pos. 4) Space Tgt.	Space Tgt. Update	Space Tgt. coordinates updated if FIX switch depressed		
(SW-3) SCAN SELECTOR SCAN A			(Lighted Push-Button) (SW-3)  	When in Scan Mode, Annunciator is lighted. Mode may be released by depressing switch, or by depressing Fix switch.
(Pos. 1) OFF	Scan A Off	Annunciator I-1 Off		
(Pos. 2) ON I-1 "On"	Scan A On	Scan Pattern A Functioning; Annunciator I-1 lighted.		Annunciator will go Off.
(SW-4) SCAN SELECTOR SCAN B			(SW-4)  	
(Pos. 1) OFF	Scan B Off	Annunciator I-2 Off		
(Pos. 2) ON I-2 "ON"	Scan B On	Scan Pattern B functioning, Annunciator I-2 lighted.		

Table 5-1 IVSS Controls and Displays (cont)

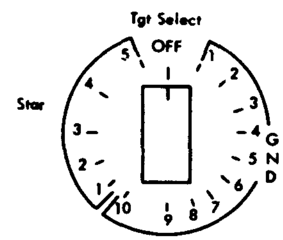
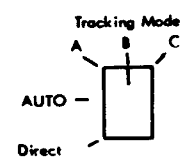
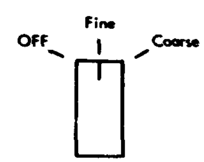
Panel: Control/Display	Position	Function	Type	Remarks
IVSS MODE PANEL - Continued				
(SW-5) TARGET SELECTOR GROUND (Pos. 1) GND TGT 1 (Pos. 2) (Pos. 10) Gnd. Tgt. 10 STARS (Pos. 1) STAR 1 (Pos. 2) (Pos. 5) STAR 5 OFF		Manual select of target or Fix Point to be acquired or tracked,	 (ROTARY SELECTOR) (without limit stops)	If Function switch (SW-2) is in Ephemeris and Fix switch is depressed, ephemeris will be updated on bases of known gnd tgts, 1 through 10. If Function switch is in Gnd TGT Update, Gnd. Tgt. coordinates as 1 through 10, as selected, will be updated.
(SW-6) TRACKING MODE (Pos. 1) Direct (Pos. 2) Auto A, 0-5^{o}/sec. (Pos. 3) Auto B, 5-25^{o}/sec. (Pos. 4) Auto C, 25-100^{o}/sec.		In Direct Mode, operator has complete control of rates. In Auto Mode, rates vary as function of position of selected Mode (A, B, C) and amount of displacement of hand control		
(SW-28) Attitude Control (Pos. 1) OFF (Pos. 2) FINE (Pos. 3) COARSE		Selects coarse or fine attitude control mode or off (no attitude control)		Fine mode will be used prior to the IVSS experiment. Attitude control system may be turned off during the experiment. Either Fine or Coarse positions enable the control stick (SW-10 and 11) for vehicle attitude control.

Table 5-1 IVSS Controls and Displays (cont)

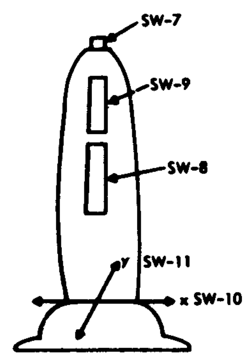
Panel: Control/Display	Position	Function	Type	Remarks
HAND CONTROL				
(SW-7) FIX SWITCH				
(Pos. 1) OFF (Pos. 2) ON (Pos. 3) ON-Auto Scan Rel.	Auto Scan Release	When in "auto scan" fix button "on" will stop scanning.	(Two Axis Controller)	
(SW-8) ACTION SWITCH (Pos. 1) OFF (Pos. 2) ON		Sw. 8 a "dead-man" switch		Switch 8 must be depressed for switches 7, 9, 10, 11 to be energized; or responded to
(SW-9) PHOTO RECORD (Pos. 1) OFF (Pos. 2) ON		Photo record enable function When this switch is depressed (SW-9) photos will be taken when fix button (SW-7) is depressed		
(SW-10) X-DIRECTION (Pos. 1) ZERO (Pos. 2) PLUS (Pos. 3) MINUS		Continuous (potentiometer or encoder type control)		
(SW-11) Y-DIRECTION (Pos. 1) ZERO (Pos. 2) PLUS (Pos. 3) MINUS		Continuous - (potentiometer or encoder type control)		
IVSS POWER PANEL (SW-27) IVSS Power		Manual application of power		
(Pos. 1) OFF (Pos. 2) STAND BY (Pos. 3) ON		All power off on the IVSS equips. Application of Heater Power Application of power for total IVSS (HV as well as heater power)	(Toggle, spade handle)	

Table 5-1 IVSS Controls and Displays (cont)

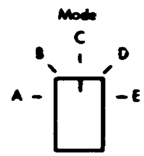
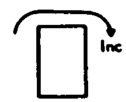
Panel: Controls/Displays	Position	Function	Type	Remarks
<u>VISUAL EVALUATION TRACKER PANEL</u> (SW-12) POWER (Pos. 1) OFF (Pos. 2) ON	Off On	Applies power to Visual Evaluation tracker. Flips mirror in PTS to change optical path (relay operated)	(Toggle Switch, Spade Type Handle) VET PWR 	Mirror for VET will return to normal position in event of malfunction or loss of power
(SW-13) TRACKING MODE (Pos. 1) Mode A (Pos. 2) Mode B (Pos. 3) Mode C (Pos. 4) Mode D (Pos. 5) Mode E		Manual selection of rates and Track types to be used in evaluation of astronaut performance	(Rotary Selector, 5 Pos.) 	
(SW-14) INTENSITY BRIGHTNESS		Controls intensity of spot to be tracked	(Potentiometer) VET BRIGHT 	
(SW-15) PERFORMANCE RECORD (Pos. 1) OFF (Pos. 2) ON	Off On	Selected control positions and Hand Control parameters are measured by the astronaut himself, without recording the results (when in the OFF pos.)	(Toggle Switch) PERFORM RECORD 	Appropriate Data Management interface must be set up by astronaut. In off position, used to maintain proficiency in tracking, or for practice prior to a recorded run.

Table 5-1 IVSS Controls and Displays (cont)

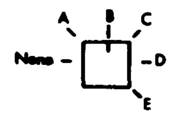
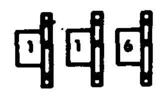
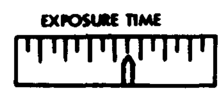
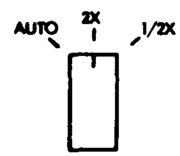
Panel: Control/Display	Position	Function	Type	Remarks
<u>CAMERA PANEL</u> (SW-16) FILTER SELECTOR (Pos. 1) Yellow 1 (Pos. 2) Yellow 2 (Pos. 3) Orange (Pos. 4) Red (Pos. 5) Neutral (Pos. 6) None		Manual selection of desired filter	FILTER SELECT 	(Functional Representation) ROTARY SWITCH (Mechanical Linkage in Optical Path)
(I-7) FRAMES REMAINING (SW-17) Set		Display -f Frames Remaining in Roll Manual set of frames remaining	(NUMERICAL INDICATOR) FRAMES REMAINING 	Each digit may be reset individually by means of the sprocket wheel to the right of the displayed digit.
(I-8) EXPOSURE TIME DISPLAY				Indicates exposure time when in automatic or manual
(SW-18) EXPOSURE SELECT (Pos. 1) Auto (Pos. 2) 2X (Pos. 3) 1/2X		Automatic exposure control. Semi-Manual exposure control select.	(ROTARY SELECTOR) EXPOSURE (SEC.) 	In "Auto" position, the exposure used is the same that is shown on Exposure Time Display. In the "2X" position, the Exposure used is twice as much as that indicated by the Exposure Time Display. In the "1/2X" position, the exposure used is twice as much as that indicated by the exposure time display.

Table 5-1 IVSS Controls and Displays (cont)

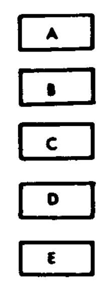
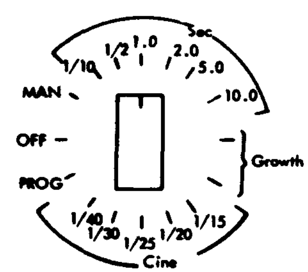
Panel: Controls/Displays	Position	Function	Type	Remarks
(I-37) FILM TYPE Annunciators		Provides operator with knowledge of film type in camera	Film Type Annunciator 	The Film carriage is coded such that a signal is fed to the camera directly (for proper exposure control) and to the operator via the film type annunciator
(SW-20) FRAME RATE			(Rotary Selector, 16 Pos.) continuous, without stops)	
(Pos. 1) Off				
(Pos. 2) Manual		Manual rate, with fix switch		In manual, switch 9 must be closed; photo will be taken each time fix switch is depressed
(Pos. 3) Pulse 1/10 sec.		Pulse, or time-controlled rate		
(Pos. 4) Pulse 1/2 sec.				
(Pos. 5) Pulse 1.0 sec.				
(Pos. 6) Pulse 2.0 sec.				
(Pos. 7) Pulse 5.0 sec.				
(Pos. 8) Pulse 10.0 sec.				
(Pos. 9) Cine 1/15		CINE, or motion picture rate		Program; computer controls photographing
(Pos. 10) Cine 1/20				
(Pos. 11) Cine 1/25				
(Pos. 12) Cine 1/30				
(Pos. 13) Cine 1/40				
(Pos. 14) Program	Program	Computer control or time of Photos		

Table 5-1 IVSS Controls and Displays (cont)

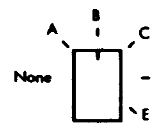
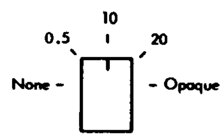
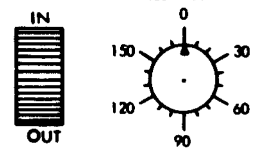
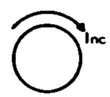
Panel: Controls/Displays	Position	Function	Type	Remarks
<u>POINTING-TRACKING SCOPE</u> (SW-21) SPECTRAL FILTER SELECTOR (Pos. 1) Filter A (Pos. 2) B (Pos. 3) C (Pos. 4) D (Pos. 5) E		Manual selection of spectral filters	(Rotary Selector) SPECTRAL FILTER 	Mechanical insertion in optical path
(SW-22) ATTENUATION FILTER SELECTOR (Pos. 1) Level A, 0.0 (Pos. 2) Level B, 0.5 (Pos. 3) Level C, 10 (Pos. 4) Level D, 20 (Pos. 5) Level Opaque	None	Attenuation Filter Selection	(Functional Representation) ATTENUATION 	Mechanical insertion in optical path
(SW-23) POLARIZER SELECT (Pos. 1) OUT (Pos. 2) IN (plus rotation) (SW-25) POLARIZER ORIENTATION		Manual insertion and rotation will result in differential polarization	(Functional Representation) POLARIZER 	Mechanical linkage, (from polarizer knob) 0-180°, continuous control type In-Out switch is rocker type with guard rails
(SW-24) RETICLE BRIGHTNESS Continuous Control (potentiometer)		Manual control of reticle intensity	(Continuous Rotary) Potentiometer  RETICULE BRIGHT	

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Table 5-1 IVSS Controls and Displays (cont)

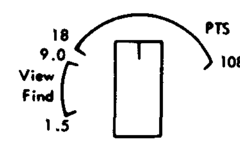
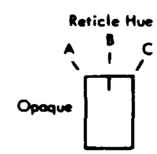
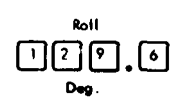
Panel: Control/Display	Position	Function	Type	Remarks
<u>POINTING-TRACKING SCOPE</u> (Continued) (SW-26) POINTING TRACKING AND VIEW FINDER MAGNIFICATION Range 1 1.5X to 9.0X Range 2 18X to 108X	 1.5-9.0 VIEW FINDER 18-108 PTS	 Manual selection of power of magnification of pointing-tracking scope View finder low magnification used during Acquisition	(Representation only) PTS MAGNIF. 	Mechanical or actual replacement of eyepiece, possible as a back-up mode. May be controlled by means of a foot pedal rather than by panel control
(SW-31) RETICLE SELECTOR (Pos. 1) Opaque (Pos. 2) Hue A (Pos. 3) Hue B (Pos. 4) Hue C	 Opaque Off Hue A Hue B Hue C	 Opaque - reticle lamp Off Reticle Lamp on, hue type A " " ", hue type B " " ", hue type C		
(SW-32) POINTING-TRACKING SCOPE Grid (Pos. 1) ON (Pos. 2) OFF		In the "ON" position, A grid is superimposed in the PTS Field of View. The Operator uses this Grid to make correction in yaw.		Rocker type switch (with guard rails)
PTS POINTING ANGLES (I-10) ROLL INDICATOR		Indicates Roll angle of the PTS optical axis relative to vehicle axis.		Window type display

Table 5-1 IVSS Controls and Displays (cont)

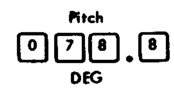
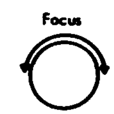
Panel: Control/Display	Position	Function	Type	Remarks
(I-11) Pitch Indicator		Indicates Pitch angle of the PTS optical axis, relative to the vehicle axis.		
Point-Tracking Scope-Cont. Decaying Tracking Circle		This circle is superimposed in the PTS field and gives a qualitative indication of the amount of time remaining for the Operator to complete his tracking task. For a precise quantitative determination the Operator must look at the Tracking time, readout on the Display Panel		Indication at left shows 75% of total time remaining. This circle will be large enough so as to be on the periphery of the field of view and not interfere with the acquisition and track task.
Point-Tracking Scope (SW-33) Focus Control		For target at a distance greater than five miles, focus is in the Automatic Mode.		
(SW-34) Focus Mode		For targets at a distance of 500 ft and greater, operator has the option of focusing manually		Toggle switch (spade handle)
(SW-35) Interpupilary Distance (Pos. 1) for Op #1 (Pos. 2) for Op #2		Provides two discrete position, pre-determined and pre-set for operator #1 and #2		Rotary Thumbwheel with two detent positions. Positions determined by measurement of the two operators prior to the mission.

Table 5-1 IVSS Controls and Displays (cont)

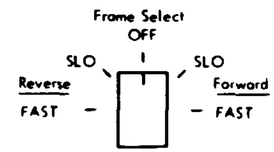
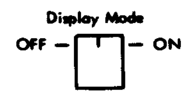
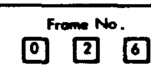
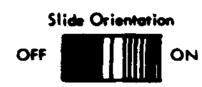
Panel: Controls/Displays	Position	Function	Type	Remarks
BRIEFING (SW-27) FRAME SELECT (Pos. 1) (Pos. 2) (Pos. 3) (Pos. 4) (Pos. 5)	 Frame reverse Slew Reverse Frame Forward Slew Forward Off	Permits operator to select aporopriate frame.		A selector switch which will control movement of frames in "FWD" or "REVERSE", both frame by frame and in slew mode.
(SW-29 DISPLAY MODE (Pos. 1) OFF (Pos. 2) ON		No briefing information displayed		
(SW-30) BRIEFING INTENSITY (Continuous)	Intensity adjust	Continuous intensity control.		Potentiometer type control
(I-9) BRIEFING FRAME NUMBER		Display of Briefing frame number		
(SW-36) SLIDE ORIENTATION	OFF ON	In the "OFF" position, the Briefing Slide cannot be oriented. In the "ON" position, the hand control is used to move the Briefing Slide for the purpose of orientation. It (the hand control) will operate as follows: Movement left - moves slide left. Movement right - moves slide right. Movement up - moves slide up. Movement down - moves slide down. Rotation - Rotates the slide. (When in the "ON" position the Hand Control cannot be used to point and track.		This switch is rocker type with guard and is slightly recessed. This prevents the slide from being inadvertently knocked out of alignment and permits the operator to rest his arm on the panel while adjusting the other briefing controls or camera controls.

Table 5-1 IVSS Controls and Displays (cont)

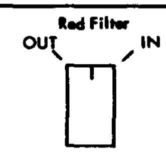
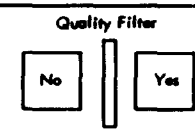
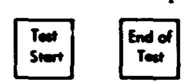
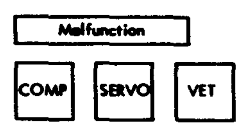
Panel: Controls/Displays	Position	Function	Type	Remarks
(SW-37) RED FILTER	Out In	Red filter is removed from in front of Briefing Frame Red filter is placed in field of view of briefing frame		Mechanical Linkage
(SW-60) Quality Filter	No Yes	The No response means that the operator would not take a picture if the choice were his. The Yes response means that the operator's opinion is that conditions are suitable at that time to take a picture. These switches when pressed hold in the depressed position for approximately two sec, so as to let the operator know that his response has been recorded but without requiring him to look directly at the switches. Both switches cannot be pressed simultaneously or while the other is depressed.		Response button used by the operator to indicate whether or not he would take picture if choice were his. Only his response is recorded. Picture taking is not interferred with.
(I-12) Test Start Light (I-13) End of Test Light		Informs operator (when lit) that test should be performed. Informs operator (when illuminated) that test has been completed.	(Annunciator Lamps) 	
Operator's Malfunction Indicators - Station I (I-14) Computer (I-15) Servo (I-16) Vet		Tells the operator #1 of malfunction in one of the subsystems.		A more detailed display of system status is provided for Operator #2 on the overhead panel. The larger malfunction light will come on in the event of any system failure.

Table 5-1 IVS^{C} Controls and Displays (cont)

Panel: Controls/Displays	Position	Function	Type	Remarks
MDDU				
Computer Display Unit		A decimal display of computer parameters, address and message. 10 digit (including sign)	Address Message 9 9 9 + 2 3 2 3 2 3	After parameter selection (on MDIU) and prior to insert, display indicates buffer storage contents.
Read Out Push Button	In-Out	After selecting address location (on MDIU), Readout button demands display of contents.	Read Out	Causes read out of contents of address shown on MDIU.
Cancel Button	In-Out	Commands destruction of buffer storage contents.	Cancel	Cancel button will not destroy computer core storage location, only buffer storage information.
Enter Button	In-Out	Contents of buffer are entered into specified address	Enter	Depressed when address and message are verified.
Computer Display Unit Power Control	On-Off	Provides On-Off power control for the computer insert and display units.	ON OFF	Turns On (or Off) both MDIU and MDDU.
MIDU				
Manual Data Insertion Unit Decimal Insert Keyboard	Zero through 9 digits, push buttons.	To select appropriate parameters for insert. (Decimal Form)	MDIU 7 8 9- 4 5 6 1 2 3 Zero	All values considered positive unless 9 (-) position is depressed fourth in sequence (-) will appear in fourth window from left on MDDU.
TARGET PARAMETERS			(Numerical Indicators)	
(I-17) Min. Line-of-Sight Distance to Target		Computed Distance of Line-of-Sight distance (Nautical Miles)	Min. Los To Target 1 1 6 3 5 N.M.	
(I-18) Time to Target		Display of Computed time to Acquisition of Target	Time To Target 5 9 0 8 Min Sec	
(I-19) Target Track Time		Display of usable tracking time in passing over target, for preset viewing angle limits	Target Track Time 0 5 9 Sec	Will normally represent time of view within a ±60^{o} angle from Nadir.

Table 5-1 IVSS Controls and Displays (cont)

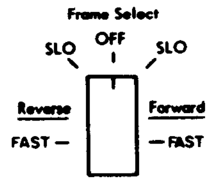
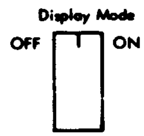
Panel: Control/Display	Position	Function	Type	Remarks
(I-20) Latitude		Display of latitude of next target of interest	LAT 60° 04.3′ N	Displays latitude of next target of interest from computer catalogued data.
(I-21) Longitude		Display of longitude of next target of interest	LONG 105° 27.5′ W	Displays longitude of next target of interest, from comp. data.
PHOTO DATA				
(I-22) Frame No.	Indicates Numbers 0 to 999	Indicates the number of the briefing film frame (on the projection screen)	Numerical Indicator Frame No. 015	Used for both identification (by association) with presented briefing material and as info for initial "call-up" of desired frame.
(SW-38) Frame Select	Slow or fast in either forward or reverse directions	Selects speed and direction of drive motor film select mechanism		Used to select a given frame of briefing material (if frame no. is known) for presentation, or to search for the desired briefing material by observing the screen if the desired frame no. is not known.
(SW-39) Display Mode	ON or OFF	To turn on or off, the complete Photo Data Control Unit.		Applies power to the Projection screen, film drive motor and slide orientation mechanism.
(SW-40) Briefing Intensity	Continuous potentiometer control	Adjusts level of brightness of the Projection screen	BRIEFING INTENS. 	Set initially for average brightness, but may be altered for optimum target resolution (for identification or placement of crosshairs).

Table 5-1 IVSS Controls and Displays (cont)

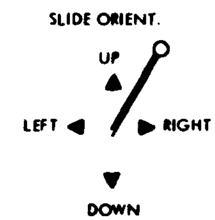
Panel: Control/Display	Position	Function	Type	Remarks
(SW-41) Slide Orientation	Swivel Stick, 360° control	Positions Film		Directional change is determined by directional pointing of the stick. Magnitude of film displacement is controlled by magnitude of displacement of the stick.
Film Projection Screen Control				
(SW-42) X Axis Crosshair Control	Continuous Rotation	Controls position of crosshair on the Projection Screen along the X axis		Used for positioning the crosshair on both the reference point and the target of interest.
(SW-42) Y Axis Crosshair Control	Continuous Rotation	Controls position of crosshair on the Projection Screen along the Y axis		Used for positioning the crosshair on both the reference point and the target of interest.
(I-23) X Axis Center	Indicates Numbers 0000 to 9999	Displays relative displacement of the crosshair in the X direction from the reference point	3 9 5 2	Information displayed is recorded when the "Target Record" button is pushed.
(I-24) Y Axis Counter	Indicates Numbers 0000 to 9999	Displays relative displacement of the crosshair in the Y direction from the reference point	1 4 8 5	Information displayed is recorded when the "Target Record" button is pushed.
(SW-43) X Axis Reset	In-Out (Spring Return)	Resets X axis counter to 0000	RESET	
(SW-44) Y Axis Reset	In-Out (Spring Return)	Resets Y axis counter to 0000	RESET	

Table 5-1 IVSS Controls and Displays (cont)

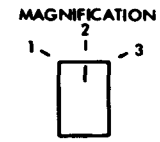
Panel: Control/Display	Position	Function	Type	Remarks
(SW-45) Magnification	1 or 2 or 3 (rotary)	Selects magnification of projected film		Position 2 is the normally used position
(SW-46) Crosshair Record	In-Out (Spring-Return)	Causes the crosshair position to be recorded (both X and Y co-ordinates)		
(SW-47) Target Record	In-Out (Spring-Return)	Causes the Target position to be recorded (both X and Y coordinates)		
VOICE RECORD				
(I-25) Recording Level	Normal position is center	To indicate level (amplitude) of material being recorded.		Used with "Record Gain" control. Used to establish proper level
(SW-48) Record Gain	Continuous (Potentiometer type)	To control amplitude (level) of material being recorded.		Used with the recording level meter indicator to establish adequate recording level.
(SW-49) Playback Volume and On/Off Power Switch	Continuous (Potentiometer type)	To control the volume (level) of material being played back.		To satisfy individual preference of volume desired.
(I-26) Tape Remaining	Linear scale	Provides indication of tape remaining		A warning indicator is incorporated with the Tape Remaining indicator to show when tape should be changed.
(SW-50) Reverse Button	In-Out (Spring-Return) detent lock.	Commands tape flow to the reverse direction		
(SW-51) Record Button	In-Out (Spring-Return) detent lock.	Causes the record head to be energized for recording		Round button to upper left must also be depressed to record (to prevent unintentional recording).

Table 5-1 IVSS Controls and Displays (cont)

Panel: Control/Display	Position	Function	Type	Remarks
(SW-50) Playback Button	In-Out (Spring Return) detent lock	Causes the read head to be energized for playback	Play Back	
(SW-53) Forward Button	In-Out (Spring Return) detent lock	Commands tape flow to the forward direction	FOR.	
(SW-54) Stop Button	In-Out (Spring Return) detent lock	Stops tape mechanism and turns off power to the record electronics	STOP	
Malfunction Panel			Illuminated Annunciators	
(I-27) PTS Annunciator		Indicates PTS out (functional failure)	PTS	No further isolation possible without manual checks.
(I-28) Power Supply #1 Annunciator		Indicates Power Supply #1 out	PS#1	
(I-30) VET Annunciator		Indicates Visual Evaluation Tracker out	PS#2 VET	No further isolation possible without manual checks.
(I-31) Servo System Annunciator		Indicates that one of the servo systems out	SERVO	Further isolation may be accomplished oy exercising the serve test switch.
(I-32) Camera Annunciator		Indicates that one of the cameras are out	CAMERA	Further isolation may be accomplished by exercising the camera test switch.
(I-33) VAZP Annunciator		Indicates that the variable anamorphic zoom projector is out.	VAZP	No further isolation possible without manual checks.
(I-34) Computer Annunciator		Indicates that the computer is out	COMP.	Further isolation may be accomplished by exercising the computer test switch.

Table 5-1 IVSS Controls and Displays (cont)

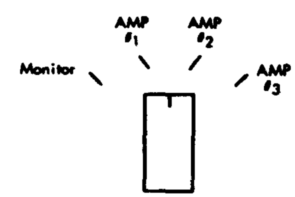
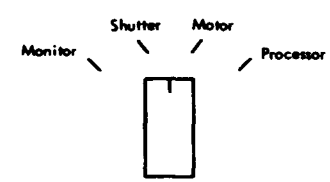
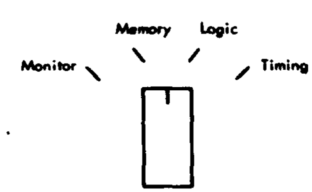
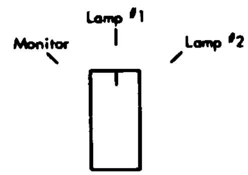
Panel: Control/Display	Position	Function	Type	Remarks
(I-35) IVSS Functional Test "Go" Annunciator		Indicates satisfactory condition of overall IVSS as a result of initiated functional test	GO	The Go-No-Go Functional Test is initiated by the "Initiate Test" button.
(I-36) IVSS Functional Test "No-Go"		Indicates unsatisfactory condition of overall IVSS as a result of initiated functional test.	NO-GO	Isolation to taulty equipment level is then provided by equipment annunciator lamps and test switches.
(SW-55) SERVO TEST Switch	Pos. 1 Monitor all Pos. 2 Monitor Amp #1 Pos. 3 Monitor Amp #2 Pos. 4 Monitor Amp #3	To select either total system monitoring of the servo system, or test of individual servo amplifiers for isolation purposes.		Used in conjunction with the "Servo Annunciator". In a monitor position, a failure in any portion of the servo system will illuminate the servo annunciator lamp.
(SW-56) Camera Test Switch	Pos. 1 Monitor all Pos. 2 Monitor Shutter Pos. 3 Monitor Motor Pos. 4 Monitor Processor	To select either total system monitoring of the Camera system, or test of separate camera functional sub-assemblies for isolation purposes		Used in conjunction with the "Camera" annunciator. In monitor position, a failure in any portion of the camera will illuminate the camera annunciator lamp.
(SW-57) Computer Test Switch	Pos. 1 Monitor all Pos. 2 Monitor Memory Pos. 3 Monitor Logic Pos. 4 Monitor Timing	To select either total system monitoring of the computer system, or test of separate computer sections for isolation purposes.		Used in conjunction with the computer annunciator. In monitor position, a failure in any portion of the computer will illuminate the computer annunciator lamp.

Table 5-1 IVSS Controls and Displays (cont)

Panel: Control/Display	Position	Function	Type	Remarks
(SW-58) VAZP Lamp Test	Pos. 1 Monitor all Pos. 2 Monitor Lamp #1 Pos. 3 Monitor Lamp #2	To select either total system monitoring of the VAZP, or test of separate VAZP sections for isolation purposes.		Used in conjunction with the VAZP annunciator lamp. In monitor position, a failure in any poriton of the VAZP will illuminate the VAZP annunciator lamp.
(SW-59) Functional Test Initiate Button	In-Out (Spring-return)	To initiate overall functional test of the IVSS.		Results of the test will appear as either a "Go" or "No-Go" condition on the annunciator lamps.

5.3 Auxiliary or Supplementary Aids

Several devices have been identified as desirable aids to the crew during conduct of the primary experiments. Efficiency and reliability of the crew must be optimized to ensure accurate and timely conduct of the experimental schedule; thus necessitating careful attention to the design and application of the supplementary aids. The briefing aid, for example, must be optimized with respect to content as well as method of presentation, due to its probable impact upon human acquisition capability. The supplementary aids, discussed in this section from a functional characteristic and operational standpoint are: (1) the Visual Evaluation Tracker, (2) the PTS Briefing Display, and (3) the Image Analysis Devices, which consist of Image Projector and an Optical Comparator. Engineering descriptions of these devices are included in Volume III.

5.3.1 <u>The Visual Evaluation Tracker</u>

5.3.1.1 Rationale

The Visual Evaluation Tracker (VET) has been designed as an extension of the capabilities of the Pointing Tracking Telescope, with the feature of rapid removal or incorporation of the device with minimal design impact upon the primary optical system. The VET provides a precise measurement of preceptual-motor tracking ability and a calibration of basic visual characteristics such as visual acuity. The incorporation of this capability in the PTS, the primary visual instrument, is considered more desirable than an approach using separate instrumentation, due to: (1) requirement for precision control of the presentation of images for tracking and for visual calibration; (2) desirability of using the same instrument for calibration as well as for the primary experiments demanding visual and perceptual motor integrity, and (3) the need for high face validity, important to flight crew acceptance of the significance and need for visual and perceptual-motor calibration.

5.3.1.2 Functional Characteristics

The method by which the VET is incorporated in the primary optical instrument is described in Section 2.3.1, Volume III. Functionally, the VET will permit assessment of crew performance in compensatory tracking as well as test their basic visual characteristics. The latter capability remains to be incorporated in to the PTS design during Phase I. A graphic task analysis of the compensatory tracking calibration is included in Section 4.2 of this volume.

5.3.1.2.1 <u>Compensatory Tracking Task</u> - Target selection is accomplished by the operator; as is the representative rate (0.5 to 10.0 deg/sec) and direction for compensatory tracking. With the IVSS in the appropriate

mode, a stimulus is presented to the sighting (right) eyepiece. A means of recording integrated tracking error over time is provided which may be stored on tape or displayed to the operator upon demand. Comparison with base-line data gathered prior to flight may be accomplished. Particular attention will be paid to this measure if difficulties are encountered in the operational acquisition and sighting tasks.

5.3.1.2.2 Visual Characteristics Calibration - It is essential to assess the impact of extended exposure to space flight upon the visual system for two reasons: (1) to gather data which, in conjunction with primary experiment data, will permit prediction of human performance on future flights, and (2) if the performance of the operational task is enhanced or degraded, it would be important to know if the effect can be attributed to the basic visual system response. In selecting the tests to be incorporated in the VET, these objectives and the considerations of the following nature were used: (1) testing vision which might reasonably be affected by exposure to flight, and (2) testing those functions which are directly involved in the performance of the primary experiments.

The proposed tests are:

- Differential brightness sensitivity
- Absolute sensitivity
- Critical fusion frequency
- Visual acuity.

The VET would be designed to measure the functions listed above, with minimal PTS weight, power, and volume penalties.

5.3.2 The Briefing Display

The Briefing Display has been incorporated as a feature of the Pointing Tracking Telescope. The device presents selected materials to the left viewing eyepiece. Provisions have been made for rapid manual access to frames and for automatic control of magnification, orientation, and angle by which the frame is viewed. A detailed discussion of the briefing requirements study is included in Volume II, while the optical design and interface requirements are reported in Volume III. A functional task analysis of the use of this device is included in Section 4.2 of this volume.

Preparation of briefing materials and incorporation of the briefing stimuli remain to be studied in detail during Phase I. It is recommended that the requirements be studied and the materials be developed by the USAF Aeronautical Chart and Information Center.

5.3.3 <u>On-Board Photographic Analysis and Measurement Devices</u>

Two devices are proposed for consideration as measurement tools for on-board determination of human contribution to acquisition and tracking, and as image interpretation and analyses devices. These are: (1) the Photo Measurement Projector, and (2) the Optical Comparator.

5.3.3.1 The Photo Measurement Projector

The Photo Measurement Projector is a console-mounted back-screen projection system with a set of precision opaque crosshairs for measuring precise locations on the screen. The observer can select processed frames, analyze the content of the photograph, and measure the location of selected points, as well as the recorded optical crosshairs. Manual and direct digital readout are provided for ease of operation and recording of results. This device provides ease of viewing, rapid access to frames, review of performance for "knowledge of results", and provides for display of images, briefing material, and instructions in a manner less fatiguing to the eye.

The discussion of human capabilities in measurement of photographic data by means of the Photographic Measurement Projector is included in Section 2.1.1. This device will be used primarily as a rapid measurement aid and as an aid to photographic screening and interpretation. A graphic task analysis of the technique of measurement and analysis is included in Section 3.2. The measurement capabilities offered by this device are considered adequate for preliminary determination of results, particularly in determining target area location and threshold criteria for LOS angular rate. Rapid access to briefing and experiment protocols is possible with this device.

The requirements for display and measurement of a variety of experimental information and data for major primary experiments other than P-1, P-2, and P-3 suggest an integrated display approach. It is recommended that the features of the Photo Measurement Projector be incorporated in the integrated display.

5.3.3.2 The Optical Comparator

The Optical Comparator is described in detail in Volume III. This device, if developed, would provide an acceptable degree of measurement accuracy compatible with precise on-board measurement of target and crosshair location over time. A well-trained observer will be able to measure with the 70-mm records to an accuracy compatible with determination of human capability to determine LOS angular rate to less than 0.2 percent. Capability for direct digital readout of position is being considered for permanent data storage on tape. Detailed analysis of the photographic data by means of this device is possible for determining presence of targets, for

analysis, change detection, and measurement of length. A consideration of the measurement accuracies possible with this device is included in Section 2.1.1. A description of the characteristics of the Optical Comparator is included in Volume III.

A parametric analysis of the optical system is reported in Volume III. Requirements for optical instrumentation and photo measurement of man's contribution to LOS angular rate determination are discussed in detail for P-1, P-2, and P-3. Design specifications and requirements for the optical comparator would evolve during Phase I from these requirements and from human factors considerations.

5.4 Mock-up of IVSS Crew Station and Control-display Interface

5.4.1 Application

A full scale mock-up was constructed of the IVSS control and display interface, reflecting probable form factors and preliminary design concepts of a two-man experimental control station. The mock-up served as a tool for preliminary procedures assessment and for control and display selection and layout considerations. As described in Section 5.1, the console layout should be considered a functional representation only, which will undergo extensive modification as types and form factors of equipment become more firm during Phase I, and the impact of additional experiments are known. Figures 5-2 and 5-3 show the mock-up and interface in its present form.

5.4.2 Design Approach

The mock-up was fabricated in three main sections as follows: (1) the structure, (2) the control and display interface, and (3) the IVSS form factors.

The structure is shaped similar to the MOL, and is approximately 6 feet wide, with a wooden-ribbed shell and a high-impact styrene covering for the vehicle simulated skin. When in the operating position, the main section is tilted approximately 60 degrees supported by collapsable 2 x 4 inch legs and completely enclosed by means of a black-out curtain. When in the shipping position, the supporting legs and black-out curtain fold into the main shell. Interior lighting of the mock-up is diffused fluorescent lighting.

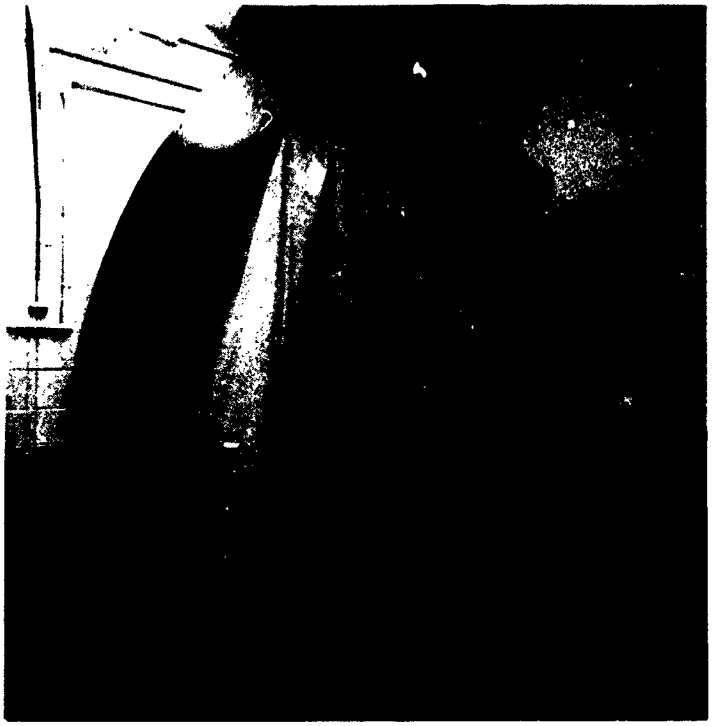


Figure 5 - 2. Experimental Crew Station Mock-Up

Figure 5 - 3. IVSS Crew Station Interface Mock-Up

The control and Display Console is semi-permanently fastened to the structure and by removing a few bolts, the panel can be removed for modifications. The panel reflects a two-man experimental control station. It is constructed of plywood panels with plastic sheets attached and supported by wooden struts, (See Figure 5-4) The appearance of the controls and displays are obtained by using artwork and a photographic process. Separate panels are used for each functional grouping and are backed by plastic sheeting. The panels are then fastened to the control panel by means of two-way tape, allowing flexibility in the arrangement of the functional panels. Plastic toggle switches are fastened to the control and display panels by two-way tape. The knobs rotate on a shaft assembly fastened to the control and display panel. The scope is built out of plexiglass and presents a view of a lighted representation of the earth from an orbital altitude.

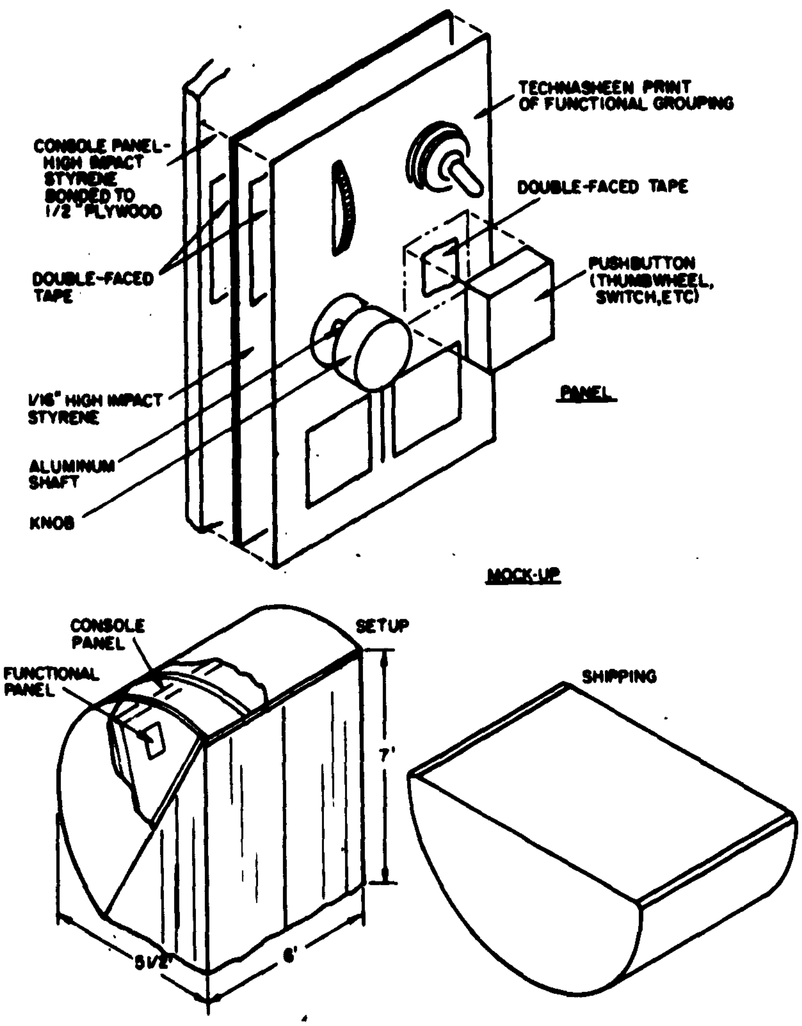


Figure 5 - 4. Method of Mock-Up and Panel Construction

To add realism, a mock-up of the hand control has been installed. A flexible duplication in appearance of the IVSS control and display console has been installed, designed in a manner permitting the console to be updated and modified with a minimum of effort and cost.

The equipment configuration form factors duplicate in appearance the IVSS Pointing Tracking Telescope, minus the servo drives and interface equipment. The IVSS crew station mock-up has been built so that form factors of the servo drives and interface equipment can be added later, if desired. Form factors of the cameras are made of plexiglass. Form factors of the scanners are made of aluminum foil and plexiglass. The main section of the PTS is made of seam-soldered galvanized pipe. The mounting board is made of plywood and masonite. The PTS form factor is painted predominantly white.

5.4.3 Proposed Application

It is proposed that the crew station mock-up be used for future demonstration and study purposes. It should be reviewed by experienced personnel which should result in operational experience and recommendations that can be applied to the system design. With modifications, it will be used for procedural development simulation during Phase I, serving later as a basic design guide for training aids development.

6.0 Flight Crew Segment Requirements Plan

The Flight Crew Segment requirements effort will consist of three parallel but closely integrated efforts; one dealing with operability and reliability of the man-subsystem interface, human engineering, another addressing the problems of training and qualification of the crew as on-board experimenters, and a third dealing with the design, analysis, and methodology of conducting the primary experiments requiring the IVSS. Close coordination will be maintained with the subsystem design team to ensure that the Flight Crew Segment requirements are reflected in the design and functional operation of the IVSS. Simulation study results will be used where appropriate; and an operational procedures evaluation will be conducted near the end of Phase I to verify procedures and the man-subsystem interface.

6.1 Human Engineering Program

The crew-subsystem interface established during the preliminary study phase will undergo extensive analysis and verification during Phase I, consistent with the design of the subsystem. Control and display panels, reflecting functions, will be modified extensively as design and form-factor information on the PTS and other equipment becomes available. The interface, as well as task and functional analyses of the operator, will be refined and will reflect the requirements for conduct of the human contribution experiments, as well as the on-board analysis of results. Impact of additional operational or experimental requirements will be assessed, including the addition of a second observer and PTS eyepiece. Applicable design standards and specifications will be used where appropriate. Crew-subsystem interface design and implementation will be reflected in a console to be developed for a procedures verification simulation study.

6.2 Training Requirements Planning

Assessment of the flight crew segment training and selection requirements will be conducted. Preliminary estimates of training time requirements and facilities will be updated and coordinated with overall Air Force training schedules, facilities, and planning for the MOL program. Training equipment and phasing requirements will be identified in terms of content material, training simulators, probable locations, and logical sequencing of activities. An integrated Flight Crew Segment training program will be submitted as an output of Phase I.

6.3 Experiment Procedures Planning

Refinement of the experimental procedures as well as the design and analysis of experimental results will be conducted in parallel with

subsystem design. The planning, scheduling, and experiment protocols will be refined, with major emphasis upon insuring efficiency and validity in conduct of the experiments and assessment of human contribution, by on-board means and in the experiment control center. Detailed analyses of crew activities will be developed on a time-line base, with particular emphasis upon decision points and complex perceptual motor or manipulative requirements. Task analyses developed for interface validation will be refined for operational procedures, which will be validated by an operational procedures simulation using an operating mock-up.

A target site analysis will be conducted, which will permit scheduling of primary experiments. Target characteristics and test site requirements will be identified. An experiment schedule, with constraints for a normal mission, will be completed during Phase I.

Application of a firm experimental design, using two crew members as subject/experimenters, will be accomplished during Phase I. Major emphasis will be placed upon the limited number of samples available, environmental constraints measurement, and techniques of on-board and ground analysis of results in real time.